5

Title: "Multi-channel proportional user interface for physical control applications"

This application is a Continuation In Part of application 09/850,385 filed 05/07/2001,

10   examined by A.K. Wong GAU/2635, and falls within the terminal limitations of the parent application.

Background Of Invention:

15   This invention pertains to the field of control systems of physical events that are to be proportionally controlled by a user via a user interface. Examples of this capability would be for; manual control of a robotic arm, control of icon or sprite on a computer game graphics display and scale model railroad layouts to improve the control of whistle and other sound effect generation or function capabilities.

20

The following discussion summarizes the rapidly expanding art of model railroad control systems and shows how many diverse elements affect the reduction to practice of adding a proportional capability to a model railroad layout control system.

25   The era of prototype (full-size) steam-powered locomotives carrying significant railroad tonnages has passed, but nostalgic model railroaders enjoy the sounds of "live steam" on model railroad layouts. In addition to steam "chuff" sounds of moving steam locomotives, bell and steam whistle effects are particularly favored by modelers.

30   A steam powered locomotive whistle is very distinctive, and many new innovations in model railroad sound systems strive to provide realistic and controllable whistles on scale

model railroad layouts. Examples of this would be modern DCC controlled sound decoders from Soundtraxx Inc. of Durango CO and ESU Electronics GmbH of Ulm Germany.

35

On non-digital or conventional analog DC controlled model railroads, the Pacific Fast Mail or PFM sound system has been very popular since the 1980's and creates very realistic sound images that are synchronized to the motion of the model locomotives, particularly narrow-gauge models. A favorite PFM sound effect is a "playable" or

40 variable pitch steam whistle, which recreates the action of a prototype engineer varying the whistle steam valve to modulate the steam whistle pitch, harmonics and intensity. This provides a lot of realistic "character" to the operation of a model locomotive. The PFM system creates the playable whistle with a hand operable pivoting whistle pitch control lever on the control unit. In the rest position this whistle pitch control lever

45 ensures that no whistle sound is generated. As the lever is actuated and its angle is changed the whistle sound effect is generated and is modified in pitch proportionally to the lever angle. Thus moving the lever up and down allows the generation of a controllable, continuously variable and playable whistle.

50 In the PFM design, the sounds created in this manner are conducted from the control unit via the layout rails to a speaker mounted in the locomotive, and optionally to speakers mounted around the layout. This arrangement permits a single high quality sound system for one train on the rails connected to a single control unit. Several other sound control units exist, for example units from Model Rectifier Corporation and Chicago

55 International that employ slider controls to allow a modeler to create a playable whistle on a conventional DC model railroad layout.

To date the only variable pitch whistle effects that have been introduced into digitally controlled model railroads are within the Marklin GmbH 1-Guage sound units on layouts

60 controlled by their Trinary square-wave digital control system. In this system a binary state accessory function control key associated with whistle control is depressed on the control unit, or throttle, that activates the whistle in the digital sound generator in the

2

model locomotive, and is also used to indirectly control a variable whistle pitch. After the locomotive whistle is activated by the whistle function key depression, the whistle

65   pitch begins to change in the digital sound generator in a manner controlled in proportion to the time the key is depressed. This provides a controllable whistle pitch with the standard Marklin binary function state control system components, but lacks the impression of continuously variable pitch that a lever or slider control creates. This Marklin control method, since it is a digital control system, has the desirable advantage

70   that it permits the realistic operation of a multiplicity of whistle equipped digital locomotives in the same area of layout tracks.

Note that the prior art attempts some types of sound varying control by employing binary (on/off) or other inconvenient or unrealistic user interfaces. For example, Wolf in US

75   Patent 6,457,681 teaches a "Doppler" sound simulation that may be initiated by the user, but this is limited by the fact that the Doppler pitch and amplitude changes of Wolf are (for a given train speed) predetermined for both up and down changes, and thus are less than realistic. This is not a true proportional effect under direct user control.

80   In this manner the prior art provides playable whistle effects or other modifiable sound, but with limitations in all the implementations.

Computer input devices have been developed to a fine art with examples such as Parsons in US patent 5,286,089 and Ono et al. US patent 5,555,004. All this work is aimed at

85   providing force sensitive computer input pointing devices that are fully integrated as a device that is manufactured as a single assembly. These mechanisms are not designed as an adjunct or upgrade to add capabilities to an existing conventional key array structure. The implied or derived force measurement is used to provide X and Y position or a selection click or double-click as a user input, and is not localized to attaching extra sense

90   capability to any single key in a key array.

An example of the use of this invention with a model railroad layout is the provision of proportional commands from a manual user input device (throttle) that communicates

with a digital layout control system connected to a model railroad layout and ultimately

95   to a decoder that makes use of these proportional commands to control sound generation

or other features that can benefit from proportional commands.

The commanding of a desired train speed is specifically defined and stated as *not* being a

proportional effect within the meaning of "proportional" used in this disclosure, since the

100   speed of the trains have been commanded by control inputs since the first electric trains

were produced over 100 years ago, and is a different effect or aspect than is described in

this invention. Note that users and even specifications often interchange the terms

locomotive and train. Typically a train comprises a locomotive and other rolling stock as

a unit for railroad scheduling and routing. This specification may use either terms to be

105   consistent with prior art, and by context it should be clear that a referral to "train" is to a

locomotive with or without extra rolling stock, and that in many cases an internal decoder

device is installed. Decoder devices may also be usefully employed for control in rolling

stock other than powered locomotives and even connected to the rails in a stationary

configuration.

110

Prior art such as Wolf, US Pat. No. 6,457,681, is an example of a layout control system

that allows control of model trains with sound and other capabilities that have some

similarities to this invention. However, this technology taught by Wolf is not state of the

art, and is surpassed with the configurations disclosed herein.

115

Wolf teaches a track control signal that "injects", adds or modulates a controlling RF

baseband direct sequence spread spectrum signal upon an AC (or DC) power signal. This

is an architectural constraint to allow the use of a mixture of "conventional" or legacy

trains (that are not modified to take advantage of increased control features) alongside

120   newer digital trains. The conventional power signal that these "legacy" locomotives

normally respond to is typically a transformer controlled variable-AC voltage that is

detailed well by Severson in US Pat. No. 4,914,431. The locomotives that can use this

AC voltage to operate are typically 3-rail O-scale trains made by Lionel, Marx, K-Line,

etc. This O-scale train market segment is often referred to as the "Toy Train" market as

125 distinct from the "Scale model" railroad market where a 3-rail track is not considered to

be visually prototypical.

By contrast, a large number of scale model railroaders in the US employ 2-rail DC

controlled trains in HO and N scales, such as those made by Athearn, Kato and others.

130 For this majority of modelers, the natural modern control choice (that still allows legacy

train operation) is based on the well-known National Model Railroad Association

(NMRA) standard for Digital Command Control (DCC). The NMRA open standard for

DCC has been in wide use since the mid-1990's and uses a track drive signal that is a

saturated-level digital bipolar square-wave waveform based on a packet technology,

135 which is a distinctly different and superior technology to Wolf for this type of

application.

Wolf is limited in the forms of modulation he can claim injected into a power signal,

because of his citation of the 1980 Keith Gutierrez CTC-16 art that also injects a control

modulation onto a power signal, in this case a modulation impressed onto DC power. In

140 the 1990's Gutierrez subsequently upgraded the CTC-16 to CTC-2000 that employs a

digital signal added to a DC power signal.

The large HO and N scale market segment cannot be addressed by the Wolf '681 art

because the provision of the Analog Zero Stretching Method for NMRA DCC that allows

145 legacy control of DC trains mixed with digital trains [detailed in section 13.3 of the book

"Digitrax Big Book of DCC"- ISBN#0-9674830-0-X , published 1999, and entered

herein as additional reference for layout control prior art] is not addressed or taught by

Wolf as within the scope of his art, and additionally, is not compatible with legacy

operation of 3-rail AC O-scale trains.

150 Impressing or injecting an RF spread spectrum control signal with variable DC power for

control of a DC conventional train, does not allow for a stationary DC conventional train

to create sound, light effects and even smoke, as would be needed to provide a realistic

model when stopped a at train station or yard. DC 2-rail modelers demand this

capability, which Wolf does not teach or provide for.

155

The DCC signal is superior to Wolf's signal because it encodes commands in the full track amplitude waveform excursions, and is easily filtered and protected from any practical system noise and track configuration disturbances and permits a mixture of unmodified (legacy) and digital trains to operate on the same tracks. DCC has been used

160   successfully for control of trains in all model scales, from Z-scale to Guage-1.

Wolf's injection of a modulated RF signal on a power signal invites problem of signal propagation and signal strength on the rails, even if a modicum of noise rejection is conferred by direct sequence spread spectrum technology.   Neil Besoughloff in the book

165   "Command Control for Toy Trains" page 93, (ISBN# 0-89778-523-1) details these problems the Wolf technology has on real layouts. The RF signal strength problem is reportedly so bad on some layouts that users must add lamps or other "transmission line impedance termination" patches to try and ensure stable and reliable operation.

170   By contrast, on DCC layouts if there is sufficient signal to allow a train to move, a decoder (designed by one skilled in the art of DCC and train control technology) is guaranteed to remain under positive control. Note that, unlike DCC, Wolf 's controlling modulated RF signal without an additional power signal is inoperative and not of sufficient power to move the trains. If this RF signal were increased to be sufficiently

175   energetic to operate a train (in range of about 12 to 100 watts), because of the antenna effects of the track wiring and rails, it would then have to be licensed by the FCC as an intentional RF radiator or transmitter and would then have; health, shock and burn hazard consequences on open rails, and would likely be impossibly restricted in allowable carrier or emission frequencies.

180   A DCC or any other known digital bipolar square-wave type of digital control signal such as; Marklin Trinary, Trix, FMZ and Zimo, is indivisible from the layout energization means, and is not simply a RF control signal riding "piggy-back" on a power signal or source.

185   The direct sequence spread spectrum modulation RF control signal taught by Wolf is significantly more complex to synchronize, correlate and decode within the recipient

decoder device, when compared to DCC. This means a higher cost, power consumption and larger size for a decoder when comparing equivalent levels of implementation technologies, which is contrary to the expectations and wishes of the market and

190 consumers.

Another limitation of the Wolf '681 art is the method by which system components are interconnected and the system is expanded.

195 Prior art taught by Ireland in US Pat. No. 6,275,739, incorporated herein by reference, shows the benefit of all system elements being interconnected in discipline via a bi-directional multiple-access data network. This Ireland prior art specifically teaches a throttle device that is connected bi-directionally to a layout control system. This throttle may also be a remote or un-tethered throttle, and gain access by a radio/RF or infra-red

200 communication link that supports this bi-directional multiple-access data network capability. [item 16 Fig 1 and 2, and lines 37-40 col 1 and lines 39-41 of col 3 of Ireland '739]. Of great importance for a system using a bi-directional multiple-access data network is that the data flows are *not* mediated centrally by a single device such as a Command Station, Track Interface Unit or equivalent central control means. With this

205 method, all elements or devices on the network enjoy the freedom of being involved in *any* type of data transfer, in any direction, by simply following; the network access rules, grammar and control capability incorporated in that device. The ease of expandability and interconnect taught in US 6,275,739 is thus both a prior art and a distinct advance over the art of Wolf '681.

210

Dunsmuir, in US Pat. No. 5,638,522, and Katzer, in US Pat. No. 6,065,406 also teach the addition of computer(s) to allow automated operations by detection and controlling the layout and expanding the way multiple interfaces may be added to model railroad layouts, and are additional prior art distinct from US 6,275,739. Dunsmuir shows a

215 hierarchical design that employs a Token ring network interconnection for *most* control elements, but that is based on the supremacy of a single master/slave PC with a complex

7

graphical user interface to animate most layout capabilities. Master/slave architecture compromises system growth choices and scalability.

All these PC control applications, including for example "Timetable" capability in the
220 Winlok 2.1 software by Digitoys Systems Inc. and the "flagman" in the RailRoad and Co. software, show examples that allow the user to pre-configure or record a complex sequence of layout actions and train commands, that can be modified by layout detection, to expand layout control. These permit, but are not limited to; the automation of routes (a sequence of turnout activations), the stopping of trains on signal/occupancy state,
225 interlocking the safe movement of trains, the display of locations of trains and the announcement or triggering of a sound file when a train has reached a location. These capabilities are well documented in the "Digitrax Big Book of DCC", including section 11 which teaches a large PUTRA automated DCC training layout in Kuala Lumpur, Malaysia that was in operation before 1999. The Digitrax LocoNet used in the PUTRA
230 simulator model layout allows the convenience of multiple PC's running the Winlok 2.1 software to be connected simultaneously to provide multiple terminals and also diagnostic capability.

A bi-directional or "Transponding" data connection to a decoder device taught by
235 Ireland in US Pat. No.6,220,552, incorporated herein by reference, teaches and allows the real time dynamic tracking of locations of multiple trains and decoder devices on the layout, *and* the interrogation of data that is decoder device state information such as; measured distance traveled, control input states (e.g. if a load is situated on a boxcar or a pantograph is down, a turnout is closed, etc.), train speed, motor load/current draw and
240 speed compensation amount, and any other manufacturer specific and configurable data or program information such as NMRA Configuration Variable (CV) settings and status reports, error conditions or downloaded sound fragments that may be employed by the decoder devices to generate sounds around the layout. A decoder device may be mobile or stationary within the layout control system and can be connected via an expansion
245 device, signal repeater or booster. The detection system is then configured to receive the response signal from the decoder device, and this in combination with encoded track

commands addressed to the decoder device, clearly forms a bi-directional data link, and flow.

250   Ames, in US Pat. No. 6,539,292, claims the ability for a system to modify its control based on the detected location of a decoder device. The Ames' '292 specification clearly shows [lines 34-37 col 4] that the Ireland '552 art meets his description and can be described as equivalent to his "bi-directional communication".

Ames states incorrectly that Ireland '552 "...can only acknowledge a specific command
255   sent to it and cannot initiate a communication on its own." [lines 21-26 col 3]. This is contradicted by the specification of Ireland '552, and Claim 7, that clearly is for a device that can respond when *not interrogated by its own address,* and is hence not limited by the rate it is explicitly addressed. A number of other clearly false statements and conclusions are stated by Ames. For example, Ames misstates the Ireland 552 prior art by
260   stating: "The Digitrax approach, like the Zimo approach, both suffer from the command refresh rate." [lines30-31 col 3 of Ames '292].

Ireland '552 explicitly teaches [lines 19-23 of col 21] that the decoder responses (that clearly meet Ames' definition of bi-directional capability) have the benefit of being "...not limited by the rate commands are sent to any single address." This Ireland prior
265   art teaches a device that can initiate a response without being constrained by the system.

Unfortunately the Ames' specification, by redefining or labeling a decoder response to a command as "bi-directional" and stating many false limitations of the Ireland '552 prior art, misleads the examiner in a matter that is fundamentally at the heart of Ames' claims
270   for novelty over the prior art of bi-directional data communication and control.

Wolf '681 fails to anticipate or teach the ability of his invention to identify the address and then to use this to track train position as it moves *around* the layout. This tracking (e.g. 'Transponding') is definitively a form of bi-directional data feedback and
275   acknowledgement. Wolf '681 only mentions contact switches or IR position sensors for location detection, and does *not* teach expanded detection of occupancy or position feedback by utilizing the *conducted track voltage or current waveforms,* or how this

expanded detection and position information then may be employed to automate or advance the control capability of the layout by any connected control element.

280   Marklin and others have employed as prior art; contact switches, IR or laser reflective/transmissive sensors, optical Bar codes, magnetic detectors and RF identification to provide detection for control and display purposes. The use of visual pattern recognition to identify and detect rolling stock has also been discussed, and color-coded swatches have been tried by the prototype railroads for visual detection and

285   control.

The Ireland '552 prior art teaches and anticipates a wide diversity of data exchange and bi-directional capability with decoders connected to the layout, including the ability to detect and alert train derailment or removal from the layout and system so the system can

290   respond and modify its behavior. Section 10.0 of "The Big Book of DCC" clearly teaches many examples of the layout control system adapting its behavior to train location feedback, and even shows an example of the system making a decision to run the train around a reverse loop if needed after recognizing the bi-directional data feedback of a transponding device address.

295

At the 1993 NMRA National Train Show and Convention in Valley Forge PA, the MiniTrix control system (from the Trix company of Germany) was demonstrated with miniature ceramic board decoders in HO and N scale that employed a Digital square-wave track control signal and a back-emf motor speed control with fine speed resolution

300   and speed/load compensation. At this time, and up to 1998, several other companies such as Marklin, Zimo, Lenz and Arnold also demonstrated digital decoders with back-emf speed/load compensation. The Umelec Company of Switzerland also demonstrated a version of speed/load compensating digital decoder with an optical sensor on the motor flywheel to provide speed/load compensation, as an alternate to sensing motor speed by

305   back-emf. All these prior art decoders employed a control strategy such as the well known Proportional Integral Derivative (PID) servo control loop method.
This allows the decoder to compensate for the slowing down or speeding up of the motor in response to a change in load (i.e. the "droop" or speed/load sensitivity), and thus tend

to hold any constant speed commanded by a user. Severson in US Pat. No. 5,448,142

310   teaches some of the control possibilities for employing the back-emf detected from a

motor on a model train, such as laboring of sounds when an increased motor load is

detected, etc.

From August 1999, Digitrax Inc. was shipping the DZ121, DH140U and HAG501

315   decoders that had back-emf load compensation called "Scalable Speed Stabilization" (

denoted as 'SS' capability in August 1999 Digitrax catalog, p38/39), and having 128-step

resolution. This allowed scalability, such that the user could adjust the "droop" or

speed/load compensation characteristics on the fly. This allowed the Intensity or droop

CV (CV57) of the back-emf PID type loop to be dynamically programmed in operation,

320   such that the droop amount (or speed/load curve sensitivity) could be changed to suit the

model and power characteristics needed. For example, a minimum droop CV57 of zero

means that the back-emf load compensation is turned off and the model behaves like an

unmodified DC motor locomotive, and this is similar to the performance of most US

prototype diesel locomotives. Conversely maximum droop CV57 setting ensures the most

325   constant train speed, irrespective of the train length and load and whether the train is on a

up, down or flat grade. In between settings of droop CV57 allow a proportionate

compensation effect. The CV57 droop adjustment is a new and separate coefficient

within the speed control algorithm distinct from the three Proportional, Integral and

Differential coefficients of a classic PID loop and conveniently interacts with all 3 PID

330   terms separately.

Most early US diesel prototypes, with the exception of the SD9, did not have load

compensation from the wheel speed to the prime-mover engine and generator. By

contrast many European prototype diesel locomotives employ a drive scheme that

335   speed/load compensates to ensure a more constant track speed to allow for busy track and

train schedules. So, with a simple adjustment of CV57 in real time the user can choose

the most realistic droop for the model to use at that time.

For US modelers with large consists of multiple engines there is another advantage to

modifying the droop CV. Here it is desirable to lower the droop CV value in the

11

340 locomotives, otherwise any differences in speed or compensation accuracy between the locomotive decoders will generate large coupler forces between the locomotives (the "pushy-pusher" effect) and can contribute to derailments. This is such a useful feature that there is an additional consist droop CV in Digitrax back-emf decoders available to automatically invoke this change when the decoder is consisted.

345

With the scalable 128 step resolution back-emf decoder capability, Digitrax users intrinsically interpret the numeric digital speed display in DT100 (or like throttles or computer based throttles) as showing the train speed in convenient units, typically as miles per hour. The value of speed curve slope CVs can also be easily modified to show
350 the speed in kilometers per hour, as discussed in the "Digitrax Big Book of DCC".

Wolf, in US Pat. No. 6,619,594, fails to be aware of or acknowledge this widely known body of prior art in the industry that directly and publicly contradicts the novelty of his claims.

355

Novosel et al, in US patent 5,855,004 teach the benefit of digitally generated sounds in locomotive decoders using an NMRA DCC control signal. This work was actually anticipated and demonstrated in the DSD2408 DCC sound decoder shown publicly by SoundTraxx at the Amherst Train show, 14 months before being added as new matter to
360 the Novosel specification.

In early 1999 ESU GmbH demonstrated a DCC compatible sound decoder that allowed the user to download to the decoder in the locomotive customizable sound fragments and a control sequencing scheme from; a recorded computer wave sound (.wav, etc) file,
365 CD or the Internet via the track. Information can also be uploaded from the decoder and sent off via the Internet for Customer Service use. The operating state changes of the ESU decoder allowed the user to custom configure these looped sound fragments for steam chuffs (or diesel prime mover) when the decoder changes from accelerating under load, running steadily and decelerating with lighter load. For diesels, the prime mover
370 pitch and volume are modulated based on throttle demand, and unique startup and

12

shutdown sounds are also part of the sound-sequencing scheme. Note that the ESU decoder allows the decoder setup to be modified or downloaded into flash or EEPROM memory even when the train is running on the layout. The multi-format Uhlenbrock "Intellibox" was introduced in 1998 which allowed the DCC, Marklin Trinary and Trix

375   formats to be interspersed on the track. This unit also allows the operating software to be downloaded and updated via an Internet connection to the Uhlenbrock website.

SoundTraxx Inc., ESU Electronics, Novosel '004 and Wolf '594 prior art only teach integrated motor, function and sound decoders in one combined module.

380

In 2003 the Dietz Company of Germany offered the NMRA a specification for a Serial User Standard Interface (SUSI) method that allows a sound generator to be hooked to a decoder with a synchronous data link employing a clock wire, data wire, a power wire for DC power supplied by decoder, and ground wire that connects via a 4 pin 1mm pitch

385   connector. However, this interface does not implement a proportional command interface and is not configured to allow the sound generator to decode commands directly from the track. Additionally the clock and data wires are dedicated to the synchronous data link and are not operable as separate general-purpose function control lines.

390   Severson ' 142 teaches the modification of sound based on back-emf load. Wolf 6,619,594 discusses storage of different chuff sounds based on load, but does not claim this capability. Novosel 5,855,004 claims storage of sounds at different workloads. All these prior arts fail to address the reality that the steam chuffs undergo a continuous change when trainloads vary and not, say for example, a series of 3 or more pre-recorded

395   sound examples.

For several years the NMRA DCC Working group has been informally contemplating a SoundTraxx Inc. request for an Analog Control instruction for the track that is usable for a part of a NMRA DCC compatible version of this invention, but this has not been taught

400   in a complete functional form and reduced to practice.

Since the mid 1990's the LocoLink products from Lake Oswego OR have shown the ability of RF remote throttles to directly control a decoder in a locomotive, without the need for external track control signals. The Digitrax and Zimo systems, before 1998,

405   demonstrate remote throttles that can operate DCC type control systems by Radio Frequency and/or Infra Red signals. The RF systems to date have been of a fixed or a limited number of discrete frequencies, and this poses limits to the number of throttles and *layouts* that can operate at e.g. a Train Show. The Digitrax RF data link employs a 900MHz band FM modulation scheme that uses Time Division Multiplex messaging

410   methods.

Wolf '681 employs an RF (intentionally *radiated*) radio link (as opposed to his additional RF spread-spectrum signal *conducted* via rails to the trains) between the remote control and TIU unit. Here Wolf uses a simple 900MHz band OOK keying (100% AM

415   modulation) method to create this radio link, but fails to teach the need for, or benefits of, other radio link *architectures* that overcome the problems both this OOK modulation scheme and RF data link design have with interference, multiple proximate users, or any channel management issues.

420   The improvements over the prior art used in this invention, and in combination, allow a greater level of realism and capability for model railroad layouts with a increased flexibility and lower cost.

Summary of Invention:

425

For model layouts using digital control systems the fundamental problem for allowing realistic playable whistle effect or any other sound modification is that the user input or control devices such as throttles have all been designed for binary state or on-off actuation of accessory function and sound devices on the layout. Prior art digital control

430   designs have made no provision for throttles to have proportional actuation of accessory function controls, excepting that rotary knobs, encoders or slide controls are allocated solely for continuously controllable locomotive speed. It is possible to mount a control

14

lever or slider on a throttle for proportional actuation accessory control, but these require extra space and add extra cost, as they are additional to the standard controls that have

435 been heretofore provided.

Prior art railroad digital control systems associate sound controls with a small array of general-purpose on-off accessory function keys or switches on the input device or throttle. This has been sufficient to date to allow a repertoire of sounds to be turned on or

440 off by the user. For example accessory function keys are individually allocated to simply toggle on or off a bell, coupler clank noise, steam dynamo, steam cylinder blow-down and other discrete effects. This array of accessory function keys for controlling effects needs to be redesigned to permit proportional control input actuation capability. This expands control capability by allowing the user interface to provide realistic dynamic

445 modification of sound generation across a multiplicity of sound effects and channels at the same time, and in real time.

It is an object of this invention to provide the additional new ability for a digital control system to dynamically and proportionally control one or more aspects of individual, or a

450 multiplicity of, sound effects or layout control functions, beyond the prior art non-proportionally controlled variable pitch whistle. New and novel sound features that may now be created and dynamically modified can be based on all of the existing digital sound fragments and individual sound effects such as, but not limited to; steam whistles, air whistles, bells, air horns, coupler clank noise, rail noise, cab noise, steam dynamo,

455 steam cylinder blow-down, Dynamic brake fans, brake squeal, wheel flange screech, smoke stack chuff, diesel idling speed, and ambient sounds like: cities and towns, passenger terminals, freight yards or country-side noises.

It is an object of this invention to overcome the limitations of prior user interfaces on

460 model railroad digital control systems and provide for a more realistic feeling variable whistle control feature. This invention allows existing accessory control key array designs to be upgraded to add proportional Z-axis or force measurement localized or explicitly attached to any existing individual keys. This allows the improved proportional

control of any feature controlled by such upgraded accessory control keys. This is of
465 great benefit to expanding the control capability of user interfaces for digitally controlled
model railroads.

It is an object of this invention to allow a combination of keys to provide a multiplicity of
proportional control aspects that can be latched or frozen at any value. This allows the
470 new proportional control method to be extended to more than one aspect of the sound, for
example from the following non-exhaustive set; the pitch envelope, the amplitude
envelope, the time base, the duration, ambient sound reflections and the number of
repetitions of the sounds, may now be modified singly or in combination. The individual
effects, and also combined sounds, may also now have dynamic volume and pitch
475 control. This permits the realistic real-time implementation of the Doppler effect (pitch
variation due to relative motion) and the simulation of the sound source fading into the
distance, or approaching, by the sound level and varying rate of pitch change. Additional
sound qualities that can now be controlled realistically in a proportional manner are;
echoes, reverberation from the environment the user attention is currently focused on, and
480 the time sequencing of events and their repetition.

A proportional control actuation key capability may be awkward to implement, and needs
to fall within the control format of the overall accessory key array, so that for example, a
steam whistle effect function key on one locomotive may be used for some other feature
485 on a different type of locomotive that has no whistle but needs available function controls
for other features. It is undesirable to allocate and specially build a non-array key that is
only associated with a single type of capability.

The solution to this problem that this invention employs is to add an extra dimension of
490 controllability to the accessory function switch array by allowing a Z-axis or force
normal to a function key to be used as an analog or continuous input *associated with that*
key. This means that the pressure exerted by a fingertip on a key may be used to both
activate an accessory function and also then be used to vary the same accessory function

by applied pressure changes. This provides a variable control input capability while
495   allowing the key to be a standard unit within a standard function key array.

There are a number of everyday items that permit proportional control by a human hand.
For example; a computer game joystick, a force sensitive eraser-head pointing device
added between keys in a computer keyboard and a force sensitive touch pad computer
500   pointing device. All these common examples differ from this invention in that the
proportional force sensing capabilities are specialized devices, and are not used to
upgrade a force insensitive general-purpose control switch array to a higher level of
control capability.

505   It is an object of this invention to specifically add Z-axis sensing capability to a key array
design without inherent Z-axis sense capability. This may be applied selectively to either
a single key or any number of keys in the array. This feature is of value since it permits
the selective design upgrade of a standard or inexpensive key array, or array of same
types of key devices, to have a new and useful proportional control capability. The
510   addition of proportional control capability is accomplished within the footprint of the key
array so outwardly to the human interface there is no need for extra tooling or package
design changes to the exterior of the enclosure supporting the keys.

It is an object of this invention is to provide for an enhanced control system capability
515   that allows the reception of a multiplicity new proportional commands and proportionally
controlled aspects from a throttle or any other network device, and then translate these
commands to new digital layout control instructions that then faithfully communicate
these new proportional commands, aspects and capabilities to the final recipient decoder
devices.
520

Thus, it is an object of this invention to allow proportional control of an effect from the
user interface through the control system to the final recipient decoder device.

525   It is an object of this invention to create a proportional command capable layout control system based on a bi-directional multiple-access data network that allows any attached device to: operate, mimic, emulate or masquerade as a manual user input device (throttle). In this way, one PC (or a multiplicity of computers), PDA's or Web Servers can be multiply connected to the layout control system and also establish further

530   connections via a Dialup PPP link, DSL, Cable TV or other type of broadband data connection, such as wireless 802.11 link, to an Intranet or the Internet. Now *any* attached interconnected device can be involved in *any* control functions and display that the system is capable of, and can now add further possibilities, including but not limited to; layout automation with dynamic state feedback of train position and state, automated

535   operations with fault detection, tolerance and recovery, mixed automatic and manual operations, exchange of data, and remote monitoring of layout operation and state. A remote device may also be configured to provide an emulated proportional control capability with a number of methods, even if proportional keys are not built in.

540   It is an object of this invention to enable the new combination of proportional command capable layout control system employing a bi-directional multiple-access data network, and bi-directional data Transponding art that allows any attached device, for example a manual throttle, PC or Internet connected PC, to track or view any of the bi-directional data extracted from a decoder, or a transponding enabled layout device.

545   The information fed back from decoders via the detection means is not required to be received, decoded or translated by the command station means, but is broadcasted and directly accessible on the network by any "interested device". An example of this Transponding art would be a Digitrax BDL16 LocoNet detector first publicly demonstrated in July 1999, employing the art of US 6,220,552 and discussed in section

550   5.2 the "Digitrax Big Book of DCC".

        It is an object of this invention to employ a frequency-agile RF radio link that has the ability to adapt the RF modulation, data encoding scheme and RF link control method and timing to allow operation with new systems and capabilities, as well as permitting

555   mixed operations and connection with legacy RF links.

It is an object of this invention to employ a frequency-agile RF radio link with frequency hopping arranged to allow a transceiver device to selectively be a member of several different non-interfering RF links in real time.

560

It is an object of this invention to provide a separate and convenient "plug and play" addition of an external sound generator controlled over a synchronous data link that is formed by the reconfiguration of multiple direct function leads. This synchronous data link is intended and capable of allowing full access to all the features of the external

565 sound generator, including but not limited to; proportionally controlled sound effects, sound effects influenced by motor speed and load conditions, sound event triggered by user commanded function keys, sounds configured by pre-determined events and the download and upload of sound waveform data and configurations from any other device communicating with the layout control system.

570

It is an object of this invention to provide an expansion of the track waveform control capability to permit more control choices and higher speeds and allow interoperation of decoder devices with differing or incompatible control technologies on these upgraded track signals.

575

575

Attached Drawings: (4 sheets)

Figure 1 details the typical physical arrangement of the preferred embodiment

580   Figure 2 details an electrical schematic of the preferred embodiment

Figure 3 details an example of a proportional user interface and system connection

Figure 4 details an improved RF transceiver embodiment

585

Figure 5 details an improved Track control waveform

Detailed Description of Invention:

Proportional key construction

590 Figure 1 depicts the key elements of the physical arrangement of the preferred embodiment of the invention in a user input device, or throttle, for a digital model railroad control system. Item 1 represents the actuating finger of a human user. The arrow, item 2, shows the direction of the force applied by the actuating finger and the resultant arrow pointing direction is considered the Z direction axis. Item 3 is the key

595 element that is touched by the finger, 1, and the associated electrical contact switching part of the key is shown as 4. A minimum force is required to actuate item 4 to provide an actuation signal on connection 24 and, while activated the applied force continues to be applied to 3 and 4 and may be increased. Items 3 and 4 are intimately related as a single key switch instance, and typically a key array has a number of these key switches

600 arranged in the X and Y plane somewhat perpendicular to the shown Z-axis. Of course the Z-axis here is denoted as being approximately perpendicular at a key instance, but keys can themselves be placed in any axis or orientation when embodied within a product.

The key switch mounting substrate is shown as 5 and is typically a printed circuit board

605 in the X/Y plane or some other form of substrate for key switch mounting. A substrate deflection-measuring or force sensing sensor means, 7, is attached to the substrate 5 by an force transmitting attachment material 6 in an orientation so as not to interfere with key switch action and permit force sensing. The attachment means 6 is chosen to be compatible with the substrate 5 and the sensor 7 and may be for example; an adhesive or

610 solder or like material. Connections 8 and 9 represent the means for conducting the proportional output of sensor 7, related to force sensed, to conditioning electronics as shown in figure 2.

The key switch mounting substrate, 5, has a finite compliance and there is a resulting key

615 switch mounting substrate deflection when a force is transmitted from the finger, 1, via key switch instance, 3 and 4. The substrate deflection-measuring sensor, 7, provides an electrical output when substrate deflection occurs due to key switch pressure or force.

Sensor 7 may in fact sense deflection caused by force on any actuated key switch in a group or array on its surface, and this deflection magnitude sensed is modified or scaled

620   by the distance the key switch is from sensor 7, and the deflection characteristics of the substrate. In this discussion the deflection of the substrate and sensor is caused by the force to be measured so the terms force and deflection are used interchangeably in this context.

625   An important aspect of this invention is that the sensed deflection is related to or is qualified by a particular actuated key switch instance in a group. This is possible because the initial actuation of key switch 3 and 4 informs the attached control logic means 25 in figure 2, via connection 24, which particular key switch has been depressed. The conditioned or amplified output of sensor 7, Vo or item 21, may then be selected via

630   input selector 10 and processed as a varying value by control logic 25 to be understood as a force value associated with the actuated key switch. Item 25 contains the logic, and possibly software, to perform the necessary processing and includes at least; a means of addressing or scanning for actuated key switches, controlling the force sensor conditioning electronics, a means such as an analog to digital converter or other data

635   converter method to evaluate the force sensor voltages and the means to communicate proportional commands derived from key switch actions to the rest of the model railroad control system.

The outputs of control logic 25 are commands and control information resulting from the user's key switch actions that are appropriately configured for the rest of the control

640   system and conducted to that system by a means that is not shown here. The details of the output connection means and proportional commands from 25 to the rest of the control system are adaptable to each type of control system and are not central to the operation of the key Z-axis sensitive proportional actuating capability of this invention.

645   In accessory function actuation usage for model railroad control, only a single key switch in the array is pressed at once, so it is possible to localize the meaning of the force sense measurements to the active key switch and do this consecutively for different key switches. When key pressure is released key switch actuation output from 4 indicates

this to the control logic 25 so force measurement is ended and the key switch inactive

650   commands may be generated to the control system.

If different groups of key switches have a single member that need to be active at the same time, then it is sensible to provide a separate instance of deflection sensor 7 for each key switch group. This allows the control logic 25 to process via input selector 10 a

655   multiplicity of independent sensors and simultaneous key switch actuations in different groups. To minimize deflection sensor cross talk between different key switch groups it is advantageous to modify the substrate deflection characteristics to mechanically isolate force coupling between key groups. This may be simply done by cutting isolation channels or slots in the substrate between the key groups, or some similar method to

660   isolate or modify the substrate force transmission characteristics. In this way it is possible to tailor the sense measurements to the desired key switch layout. If only a single sensor 7 is used then clearly input selector 10 devolves to selecting a single force sensor output.

The deflection sensor employed for 7 may be any one of the many well known devices

665   that provide a proportional output related to strain or deflection coupled to them, such as piezoelectric strain sensors, resistive strain gauges, capacitive force sensors, inductive force sensors, conductive foam force sensors, conductive rubber force sensors and force sensors based on conductive plastic materials. To avoid the complex and sensitive electronic conditioning required for conventional resistive strain gauges, it is

670   advantageous to employ a high output piezoelectric crystal device as a force or deflection sensor in this invention. Piezoelectric devices are conventionally employed as sound transducers, both for generation and reception of acoustic energy, as solid state accelerometers and as pickup sensors for gramophone records. These devices are inexpensive and are readily configurable for an unconventional use in this invention and

675   have the advantage of having high sensitivity and output as a force sensor.

Some throttle devices benefit from, and strive for, a compact design so as to be easy to hold in the hand. The usage of a piezoelectric sensor in this invention also permits the valuable dual-usage of the sensor 7 as a both a force sensor and as an acoustic generator

680   for aural feedback. This novel dual-usage capability of the invention allows for cost and
       space savings, since a separate sound generator is not required.

       Figure 2 is a preferred embodiment of the electrical arrangement, or schematic, of the
       invention. Force or deflection sensing piezoelectric element 7 is coupled by connections
685   8 and 9 to the conditioning electronics sense node 17 and reference or ground node 18.
       The output of the piezoelectric sensor is a high impedance, so buffer transistor 20 is
       employed so that output voltage, Vo, developed across resistor 19 and on link 21 is
       isolated and does not load sensor 7. The buffer transistor 20 is shown as an insulated gate
       n-channel MOSFET device, but a bipolar transistor or a high input impedance analog
690   amplifier could also perform this function. The buffer transistor is powered from a
       supply voltage Vs, item 22, that is chosen to provide an appropriate voltage range to be
       routed by connection 21 and input selector 10 and then to control logic 25.

       A piezoelectric crystal develops voltages when the crystal lattice undergoes deformation
695   and these are picked up on conductive electrodes on the surface. Since the crystals are
       essentially insulating in nature this voltage appears to be very high impedance or
       electrostatic in nature. Because of surface contamination or defects in the crystal, a static
       deflection will result in the deformation-induced voltages decaying slowly in time. This
       means that the crystal output voltage will typically decay slowly over several seconds or
700   appear to have low frequency cut-off or DC output drift.

       To overcome this problem this invention employs an electrical precharge or voltage bias
       Vb, item 23, on the piezoelectric sensor 7. Low reverse leakage diode 11 and resistor 12
       are employed to precharge sensor 7 to the bias supply Vb, item 23. When the associated
705   key switch 4 actuation scanned by control logic 25 indicates that sensor 7 is required to
       be sensing Z-axis force, then control line 16 from control logic 25 is asserted to make
       transistor 15 conducting. This has the effect of isolating the bias voltage Vb from sensor
       7 through a now reverse biased low-leakage diode 11. The voltage developed by 7 from
       sensing substrate deflection is configured in polarity for the finger force direction, 2,
710   shown in figure 1 to be opposite in polarity from the positive bias voltage Vb. This means

that an increasing force sense voltage will be negative across the precharged sensor 7 and will act to lower the voltage on connections 8 and 9 in proportion to the applied force. This lowered voltage is at sense node 17 and is then buffered by 20 to the rest of the electronics. The control logic 25 acts to correctly sequence the control needed to scan the

715 switches 4 and measure and interpret the varying voltage derived from sensor 7.

If control logic 25 determines that key 4 as been actuated for a long enough period to permit a predefined amount of sensor voltage decay, then it may perform another precharge of the sensor, 7, and still continue operation. Subsequent precharges may be correctly accounted for by noting that the finger force cannot vary much within the

720 typical millisecond period used for a precharge of 7. Thus the measured voltage values before and after the precharge must effectively represent the same force, so the control logic 25 can correctly associate these two measurements in a continuous manner and present an output measurement that has been compensated or corrected for sensor voltage decay. This correction process of the invention overcomes the limitations of the

725 piezoelectric sensor by effectively providing for a DC level restoration and steady voltage output from an inherently unstable DC drifting sensor.

Control line 14 is employed to control low output-leakage transistor 13 to create a sound output when the sensor 7 is not being used for force measurement. When not measuring

730 force, transistor 15 is non-conducting which allows precharge of sensor 7 via 11 and 12. In this state a sequence of timed on and off conduction periods of transistor 13 will create a sympathetic varying voltage, swinging from approximately zero volts to Vb, across sensor 7. The value of Vb has been chosen to be sufficient for this AC voltage to provide an acoustic or sound output from sensor 7. The conduction periods of 13 and timing are

735 chosen to provide a suitable tone and duration of the sound or beep. The coupling of sensor 7 to the substrate by 6 ensures that when acting as a sound transducer the sound energy is effectively conducted into the substrate and environment of the throttle unit.

The preferred embodiment shown in figure 2 is not intended to limit the means of

740 implementing the essence of this invention. There are numerous circuit arrangements that can perform the processing steps and overall function of this invention and still

employ the concepts shown herein. The usage of the proportional commands generated by this invention is not intended to be limited solely to whistle pitch control.

745 In figure 2 the value of Vb is typically chosen to be in the range of +8 to +16 volts DC. This provides a sufficient voltage for sounds to be generated by typical piezoelectric devices such as a disc element in the range of 3mm to 45mm. The schematic of figure 2 is specifically crafted in a manner so minimum supply current is consumed when no key actuation or sound generation is occurring.

750

Since the piezoelectric element has effectively bilateral transformation characteristics, a given output force or deflection will result for a set input voltage as a transducer and vice-versa as a sensor. Thus the voltage range for sensing and sound generation can be configured for good performance with inexpensive control electronics.

755

Accordingly the circuit of figure 2 may be easily configured with an appropriate piezoelectric sensor to operate with a single logic driver device that incorporates a high-impedance third operating state or tri-state output. In this way, a tri-state gate operating in its normal driven high and low state can connect to leads 8 and 9 of sensor 7 and drive

760 it with a sound generating square wave of the amplitude of its logic supply, for example +5 volts for a CMOS logic device. Driving the logic output high also performs the precharge function and then immediately switching the logic output to the high-impedance or ti-state level then permits force sensing. The sense node 17 is still buffered by 20 or any other equivalent high impedance amplifier. If the proportional output

765 voltage of sensor 7 is too low, then the buffer device 20 may also be reconfigured with additional components to provide any needed voltage amplification as well as high impedance buffering.

Note that with this configuration it is also possible for the precharge to operate by driving

770 the terminals 8 and 9 to a zero volt level with a logic output low level. In this case the sensor connections 8 and 9 are reversed so that an applied force creates a positive voltage

at node 17. Here control logic 25 can measure the force voltage directly referenced to ground and does not need to subtract the offset of the bias voltage Vb.

775   In addition to the alternate use of logic gate devices noted, logic controlled low-leakage analog bilateral switch devices may be employed by anyone skilled in the art of analog electronics design to generate the precharge voltages and sound-generating voltages, as performed by devices 13 and 15 in figure 2. These same analog bilateral switches may also be employed in the input selector 10 to perform the voltage selection or multiplexer

780   function. If input selector 10 has low leakage and high input impedance suitable for the sensor employed, then the buffer stage 20 and 19 may be eliminated and sense node 17 may be coupled by connection 21 directly into 10. These variations may be useful to cost-reduce the electronics needed when a multiplicity of force sensors are used to create more than a single proportional control key.

785

With an array of piezoelectric sensors in different groups of key switches it may not be necessary for all sensors to generate sound. In this case only the pre-charge and buffer capability are needed for units that do not make sound. In this configuration input selector 10 is used to select the appropriate sensor voltage when an associated key switch

790   is actuated. The extra conditioning electronics employed by each sensor instance is not shown here since it simply is a repeat of the electronics presented here. Extra control items performing the function of 16 and 14 for extra force sensors are likewise not shown since they are simply repeated as extra outputs from control logic 25 as needed.

795   Item 26 represents a second key switch actuation input associated to a second sensor unit and additional conditioning electronics with a voltage sensor output 27, connected via input selector 10 to the control logic, 25. When 26 is actuated, control logic 25 selects the associated sense voltage via input selector 10 and can time-share and sequence its processing capabilities amongst a multiplicity of force sensors to provide multiple

800   proportional control keys.

If a multiplicity of key switches is to be associated with a single force sensor, 7, then it is advantageous to calibrate the force coupling strength of each key switch so that all key switch pressures may be equalized in the proportional control values sent to the layout

805   control system. This may be performed at manufacture by applying calibrated forces to each key switch in turn and having the control logic 25 measure the force voltages generated, calculate appropriate calibration constants that allow force measurement normalized to the reference forces, and then save these in a non-volatile memory. These calibration constants are fairly repeatable for units manufactured with reasonable

810   tolerances, so the calibration performed on a reference unit may usually applied to other units manufactured in the same process. In this manner the required accuracy and control range may be obtained from the force sensing key switches.

A novel possibility is to build the key switch array purely with force sensing switch

815   elements. In this variation we merge the key switch actuating function, 4, with the force measurement function, 7, in each key instance into single outputs that are conditioned and then selected by input selector means 10 and processed by the control logic, 25. A key actuation decision is made by a force threshold decision means within control logic 25 by setting a threshold force level to signify initial key action. Subsequent forces

820   above the threshold level then are interpreted to be proportional control inputs. The invention methodology applies the same procedures for proportional command generation with this key construction method. It is possible to still generate sound, and a precharge cycle may also be employed if a suitable transducer is employed. Mechanical isolation may not be needed on the key mount substrate since the force sensors in this

825   arrangement are only coupled to the switch they are used to measure forces on.

Preferred embodiment within a layout control system

Figure 3 shows an example of the preferred embodiment of proportional control keys in a manual input device (or throttle), 28, that is connected via data interfaces, items 31 and

830   32, to a bi-directional system data network, 36, and then to a Command Station, 37, to form the basis of a layout control system that this invention upgrades in capability to proportional control.

An encoded square-wave digital track control waveform formed by the track output (or

booster section) of Command Station, 37, is carried by track connection 38 to the train

835   tracks, 39, and then to a locomotive, 40, which is on a track section that has been

electrically separated, as needed to allow track occupancy detection and/or bi-directional

data transponding detection capability with the layout detection system, 47.

For a proportional control capability, the system must now be configured or adapted to

840   allow distinct new proportional commands generated through a device such as a

computer or PC, 68 or throttle, 28, to be communicated over the network, 36, using new

network proportional commands specifically assigned for this purpose. Further, the

Command Station must now be able to parse or decode any network proportional

commands and then address and encode these into the appropriate track control

845   waveforms for distribution to the targeted decoder device on the layout.

A new throttle or input device message must be created that allows: (1) the selection of

the address or identification of the targeted decoder device and the type of waveform

encoding to be used to encode the resulting proportional command, (2) an identifier for

the proportional channel to be controlled, (3) the actual proportional data to convey and

850   (4) error control and other information to ensure proper delivery of the message in the

layout control system.

Since the Command Station, 37, may be capable of sequentially interspersing different

types of encoded track control waveforms, for example the Digitrax DCS100 Command

Station has allowed mixed DCC and Marklin Trinary operations since 1995, this is why it

855   must also be possible to choose the track coding to be used for encoding this proportional

command. Since there are many choices for track control waveforms that may be

employed with this invention, a decoder device on the track such as 41 must also be

configured to detect, decode and process the appropriate proportional commands encoded

on the track waveform and then convert the implied action to a proportional effect or an

860   aspect of an effect.

There has not been a reduction to practice of a fully proportional control capability

before this invention, so the track encoding used by the Command Station and understood

by a decoder device may be chosen in any convenient and compatible manner for implementation.

865   Thus, the addition of proportional capability to a layout control system has far reaching effects and burdens on many system elements. For this reason the commands and system elements must be designed and then upgraded carefully within the guidelines noted here for proportional control to be successfully implemented. The nature and control capability of the system is dramatically modified once a proportional capable input

870   device such as a throttle is added, but a lot of prior changes must be implemented in the underlying system to allow this proportional expansion to be possible. Thus the proportional upgrades to the system are a pre-requisite new capability and are latent until actively used by an input device that allows the initiation or generation of an actual proportional command. Usage of a standard non-proportional user input devices on a

875   layout control system that has the new proportional capability does not invoke or enable proportional control.

Items 48 and 49 represent detection components coupled to track connection 38 that allow detection of occupancy and/or transponding (bi-directional) data from the multiple

880   tracks, 39, to be derived from the track control waveform voltages and currents for the layout detection system, 47. A tracking buffer/filter, 79, is employed within the logic of the layout detection system, 47, to ensure occupancy detection and transponder tracking and feedback data is filtered, stabilized and more reliable in the face of track noise and loss of pickup etc. This tracking buffer/filter, 79, provides a data source to the network

885   that can be interrogated even whilst the underlying detection decisions are being processed. The tracking buffer/filter employs threshold-weighted decisions based on weighted averages of detection events and hysteresis to reject perturbations in the detections, so as to present a stable detection result to the rest of the control system. An example of this layout detection system would be the art described in Ireland 6,220,552

890   and divisional patents, and embodied in a Digitrax BDL16 detector device. Note that the occupancy and transponding data detection and layout feedback can occur on non-DCC digital track waveforms and even on DC powered layouts.

Item 41 represents a decoder device mounted in the locomotive, 40, that connects
895   electrically to the tracks, 39, to get power and commands and controls; a motor, 43,
lights, 44, electric uncoupler, 46, and a smoke generator, 45.

An additional expansion of external sound generator, 42, is connected by function control
lines, 77, to the decoder and may powered from the tracks by connection, 78, as an
alternative to getting power from the decoder. An expansion RF transceiver module, 98,
900   is connected by an expansion link, 80, for data exchange and control by the decoder and
also can get its power via the decoder from the tracks or a battery in the train. These
expansion units may be installed as desired to add new sound and control capability to
the basic locomotive.

905   The requisite batteries and/or wall power sources to energize this layout control system
are not explicitly shown here, but are understood as provided as needed to enable the
system to function as described herein.

Throttle device

910   Item 51 is an example of a user interface display on the throttle, 28, that can show a
multiplicity of sets of alphanumeric data (54) and other status information, (52,53 55 and
56) to the user, including but not limited to; train number and speed (optionally calibrated
by user to be in mph or kph units), location of the train, programming information, motor
load information, motor or decoder temperature, system status information, static
915   function states (52), layout signal indications as seen from the train cab (55). This
display can be fabricated with LED's, LCD's, EL or VF panels or any combination of
display technologies. The display may alternate element usage to show different data
types at different times (in different "contexts" or focii) or may have sufficient dedicated
elements to show all the desired information at the same time.
920
Item 50 represents a speed control knob, which can be a rotary encoder or potentiometer
or a slider type control or switch array or other device allowing a user to predetermine, or
select, a desired speed setting. This is typically the user interface item dedicated to train
speed setting. The speed control knob, 50, can also have an associated switch that allows

925   an extra axis of hand motion, such as pressing down on the knob (a "click"), to invoke a

control function such as completion of a locomotive (train) address selection process or

even a multiplicity of actuations for additional controls, such as a "double click" to

change locomotive (train) direction of movement.

930   Item 30 represents the throttle control logic that animates the throttle capabilities and

creates the user interface and processes information bi-directionally from the control

system. Item 29 represents the user interface logic that allows the throttle control logic,

30, to process; the key (items 57 through 67) presses and pressures, the speed control

knob, 50, and the user interface display, 51. The individual wires and circuit elements

935   inside the throttle are not shown here, since they would clutter the drawings and are not

needed for one skilled in the art of electronics and user interface design to create these

modules and functions from the information provided herein.

System internetworking and expansion

940   The bi-directional system data network, 36, allows all devices that co-operate to provide

functionality and form the layout control system, to exchange data without the need for a

central mediation for this data flow. It is the intention of the bi-directional system data

network to provide network bearer that will conduct the backbone data communications

transparently irrespective of the data type. For example, an instance of a PC, 68, may be

945   attached via a link, 69, to the bi-directional system data network, 36, and/or another

instance of a PC, 70, can also be connected via another link, 74, and then allow a further

external data connection via item, 72, to the Internet, 73. An instance of the Internet, 73,

may also be replaced by a reduced sub-set such as a Intranet.

Any PC or other network device can generate messages and emulate the functions of a

950   manual input device or throttle, 28, and may also extend the display and control

capability of a throttle, by virtue of increased resources such as a VGA LCD display,

mouse etc. Any device that operates as a throttle or a throttle emulator, or that can

execute control software is considered a control input means.

955   The item 72 external data connection can be any type of connection that allows TCP/IP
       or UDP protocols to be transmitted in both directions to form a connection to the Internet
       or a subset or any local Intranet branch, such as; 10Mbps/100Mbps/1Gbps Ethernet,
       Wireless 802.11x /WiFi wireless access point or other data or network modem such as a
       DSL/Cable modem or a Telephone data modem. With broadband connections the data
960   transmitted can be more rich than simply layout control commands and status, and now it
       is possible to exchange multimedia content and information throughout the layout control
       system extent, so for example a camera mounted on a train can be viewed remotely, or
       sounds and conversations can be sent via the network backbone 36, etc.

965   A PC, 70, may implement a layout control program such as suggested by Katzer,
       Dunsmuir or other software such as WinLok by DigiToys Systems Inc., and can be
       configured to provide remote client access to the system or throttle emulation and/or user
       interface display from another PC or other type of information appliance or device on the
       Internet.
970
       Alternately the PC, 70, can implement a Web server interface using TCP/IP and link 72
       to the Internet and provide a layout control channel via link 74 back to the layout control
       system. With this method the remote Internet device or information appliance may then
       employ any of the well-known Browser software programs that can then operate or
975   monitor the train layout and provide a user interface display from any location with
       Internet access, since the Web server translates layout state and control information to
       graphics, symbols and text that a standard browser can interact with.

       Once a TCP/IP connection is established, a remote Internet device has access to all
980   information and data flows on the bi-directional system data network, 36. Multiple
       instances of 70, 74 and 72 running different software types can provide a multiplicity of
       different interfaces or "ports" to the Internet or other Intranets.
       The backbone data network, 36, and its command grammar and access rules is a
       significant advantage over the Wolf single connection Master/Slave architecture, and
985   allows multiple types of data connections and devices to operate simultaneously

independently of any Command Station or TIU. An important distinction for adding a multiplicity of PC's and even a multiplicity of Internet access ports, data or multimedia channels is that the PC's are added directly to the *layout network* and add capability organically to the network as a whole, and not just limited to the TIU or another PC in the communication chain.

990

Note that PC's 68 and 70 (and throttle 28, detector 47 and *any* other additional system devices) are not limited in their connection and interaction to just the Command Station 37 (equivalent to Wolf's TIU), but can directly converse across the network and

995 exchange; data, control software, control software microcode, diagnostic information, messages, graphics display data, sounds or other multi-media data to another device and not involve the Command Station at all. This ensures the layout control system is not limited by the capability and features of a central Command Station/TIU which can rapidly become a data and speed bottleneck as systems are expanded.

1000 All data on the bi-directional system data network, 36, is broadcast and visible to all connected devices and this visibility can also be conveyed faithfully by TCP/IP data encapsulation as a network extension to any remote Internet information appliance. Even though any data is broadcast it may be directly or indirectly addressed to a recipient device and the data content, or 'payload', of any message can be any data needed to

1005 establish a link and exchange any type of data needed.

Examples of this are the ability of the PC's, 68 and 70, to send addressed PEER-to-PEER data, text and signal display messages and get key responses from a throttle(s) 28, across the network without any intermediary or Command Station (37) or its internal control software being involved. Additionally the PEER-to-PEER and other commands can be

1010 used to communicate software updates that can be addressed to any device connected and addressable directly or indirectly from the network or its extension to the Internet.

An external combination microphone and headset, 75, can be plugged into the throttle along with a "press to talk" or VOX switch, 76. The talk/record key, 64, can be used as

1015 an alternative transmit key to item 76. This then allows the user to record or send sounds, voice messages and conversations as encoded data via the bi-directional system data

network, 36, as a (1) broadcast to all devices such as throttles, PC's etc or (2) private narrowcast to a specific device such as a dispatcher at a remote PC on the Internet. This means that the common radio headsets/walkie-talkies (used for communication with a

1020   dispatcher or other train engineers) can be combined with their throttle into a single convenient unit, so there are less items to carry.

Note that the piezo-electric key-pressure transducer (or other speaker) may also be added inside the throttle to act as a speaker along with a separate microphone to allow a bi-directional voice or sound link over the system, as an alternate to a headset, 75.

1025

Since the user interface allows changing key focus and meanings as user input modes are changed, the talk/record key, 64, can also be used to signify the wish to 'record' sequences of switch commands and train controls when the throttle is in Switch (turnout) control mode, and then these "macro" sequences can then be stored in an ALM route

1030   module of Ireland '739, or any PC or other device attached to the backbone network, 36. Again these features involve elements distinct from the Command Station/TIU, 37, and the ALM or similar route and control data can be accessed and edited from anywhere on the network, and is distinct from the Wolf art. Naturally it is also possible to allow selective read-only and/or copy protection of the database content available on the

1035   network.

The user interface display features configurable alphanumeric text areas and icon displays close to input keys, so it is advantageous to allow the formation and control of "soft keys" in the interface in addition to any fixed function keys. These soft keys change focus with the change of control functions and modes and are a concise way of

1040   adding numerous additional proportional key capabilities without requiring excessive additional dedicated keys. The keys 61, 57,58, 66 and 67 are closest to the display and these can be used in conjunction with display message choices to provide a context modifiable key input capability. Alternately these five mentioned keys can be moved and replaced with extra-unmarked keys with meanings set by the adjacent display messages.

1045

The user of the throttle, 28, can also execute a FIND command key, 65, to obtain the *latest* transponding position information directly from the layout detection system, 47, so

it can immediately display and update of the position of the train that it is presently controlling (or focused on) from a tracking buffer/filter, 79, embodied in item 47.

1050 Note that all the detection information such as Transponding position and DC block occupancy information that can be generated by the layout detection system, 47, is immediately and continuously broadcast on any change detected, over the network, 36, without the intervention of the Command Station 37.

With this architecture it is possible to configure the layout detection system, 47, to be
1055 used on a DC layout *without the need* for the Command Station, 37, (or equivalent TIU) so the network approach, as embodied for example in the widely used Digitrax LocoNet, provides a very flexible and improved control strategy, different to the art and architecture of Wolf.

A further example would be the interconnection via LocoNet of a Digitrax SE8 signaling
1060 system with a BDL16 occupancy detector to a DC layout that can then be configured to provide integrated signal control and turnout control using a throttle and a PC, without a Command Station or any square-wave type control signal on the tracks.

The initial use of the FIND key, 65, for a selected decoder address or train alerts the
1065 throttle control logic, 30, that the user interface display, 51, should now additionally display position information along with; the train number, speed and other displayed state information, and *then* subsequently track and display the changing position information as it is broadcast over the system. Since the invocation of the FIND that triggers the position display in the throttle can be asynchronous to the ongoing detection process, and
1070 the throttle may not have been following the position information, the initial actuation of the FIND will cause the throttle to *also request* the current stable detection information directly and only a copy of this information from the *tracking buffer/filter* embodied in detection system, 47. This is only done to ensure correct synchronization of display information. This action is incorrectly interpreted in Ames' 292, and in fact the FIND key
1075 does *not initiate a location inquire packet* to the decoder, and the system is already tracking this decoder before the FIND can be used on the throttle.

The Digitrax BDL16, and successive detection devices are also capable of other bi-directional data feedback methods as stated earlier. For example Operations Mode

1080 Programming readback of CV's is possible, so a user throttle (or PC) can read back decoder operational information such as back-emf settings (Digitrax CV55 to CV57) and error/diagnostic information (CV30) while the decoder is moving on the layout. In particular CV30 has flag/status bits to indicate motor overload, function lead problems and other status information and these can be viewed diagnostically from *any* device that

1085 is in communication with the layout control system. The present back-emf voltage settings (conveying load), motor current, function lead current, distance traveled and input line states can also be determined from a remote location, even the Internet.

Note that sections; 5.2, 10.1,10.3,16.2 and 16,.3 of the "Digitrax Big Book of DCC"

1090 teach that the (bi-directional) feedback data from a detector like the BDL16 can be used by numerous types of devices (including PC's) in communication with the system and can be configured to; be used to display layout states, allow modification of layout behavior and automated control.

Using detection, position and bi-directional data feedback, expanded control capability

1095 along with enhanced worldwide Internet broad-band communications, it is realistic for a remote application such as the program "Trainz" or other simulator software, such as Microsoft "Train Simulator" to allow remote operation of layouts in cooperation with local manual operation layout engineers and dispatchers that provide full sound, vision and status display to all participants. This would provide a mixture of a "virtual reality"

1100 train layout(s) and operations merged with some "real reality" layout aspects. This combined layout configuration with the addition of proportional control capability, further enhances the modeling realism, accuracy, controllability and enjoyment.

Untethered data links

1105 Items 31 and 32 implement the data connection between the throttle, 28, and the bi-directional system data network 36, and may also link to RF transceivers 33 or 34. This data connection may be via a tethered or hardwired connector arrangement, for example

by RJ12 style Telco jacks and plugs, that allows the bi-directional exchange of data, symbolized as item 35, from the throttle to the system via wire connections.

1110 Throttles can configure to an untethered mode employing an Infra Red or RF wireless link that is automatically enabled when a direct tethered (wired) link between 31 and 32 is detected by the throttle as disconnected or inoperative.

Item 33 shows an RF transceiver that can communicate with another RF transceiver, 34, attached to the network interface, 32, and able to operate as a proxy data connection to

1115 the bi-directional system data network, 36, and allow the throttle via 31 to have full bi-directional data access as if it were tethered.

Note that in instances where data response back to the throttle can be selectively ignored, a lower cost one-way (simplex) IR or RF link can be employed by the throttle in sequential combination with tethered operations for a lower cost and power consumption

1120 untethered link capability.

To allow operation of a multiplicity of untethered throttles (and/or PC's) on a layout control system, it is advantageous to use a time diversity or burst-message scheme such as Time Division Multiplex (TDM) to allow many short duty cycle messages to share the

1125 bandwidth and available time on a single RF frequency. Additionally the burst-packets employ an address header to identify a unique layout ID (as routing information) that the message is addressed to. The preferred implementation of the RF link is a FM modulated frequency agile transmitter and/or receiver, although other methods may be employed. The FM carrier modulation method offers the advantage of the well known "FM capture"

1130 effect, due to the non-linear addition of in-band IF 'noise', to allow multiple transmitters on the *same frequency* to effectively send interference-free at the same time to the closest FM receiver. Additionally, multiple instances of item 32 and 34 combined as RF connections can be added to different parts of the bi-directional system data network, 36, and can co-operate efficiently via the network architecture to provide a distributed

1135 coverage area that is greater than that of a single instance of 32 and 34 in combination with any untethered throttle. This then is an example of an RF data link engineered for space diversity. An AM or OOK modulation based system cannot create this type of stable space diversity. Note too that co-operating pairs of instances of 32 and 34 can also

be used to extend the backbone network, 36, wirelessly and transparently to other areas with the same ID.

1140

Using this space diversity and TDM combination it is possible for a multiplicity of separate ID layouts (e.g. modular layouts at a train show) to operate with many throttles each in the same building at the same time. For example, at the 1999 NMRA Train Show

1145 there were up to 7 separate Digitrax radio equipped layouts, each with 4 to 10 throttles, operating within an approximate 40,000 square foot floor plan at 916.500 MHz, with no reported reception problems or interactions.

Improved RF data link

1150 A preferred embodiment for item 35 data exchange (and even links 69 and 74) is a bi-directional or duplex untethered link. To further expand the number of throttles that can operate in an area, it is useful to employ a frequency agile transceiver, so the systems can employ frequency diversity (i.e. different RF frequencies or channels) to expand capacity and avoid interference. Allocating a single frequency for each layout to share for all its

1155 throttles is a possible strategy, and each throttle transceiver can scan the RF spectrum to find a particular fixed channel with a matching or desired system ID to then operate with. However, since there are variable sources of man-made interference on e.g. the 900MHz ISM bands, this is not the optimal strategy to use with an RF transceiver that is frequency agile.

1160 An optimal operating strategy for maximum throttle and layout numbers in the face of possible RF interference is to employ a pseudo-random ordered list of hopping frequencies, or a time-variable frequency diversity. In a hopping codeset system all transceivers recognize a fundamental time period for dwelling on each of the channels before stepping to the next frequency in the codeset in synchrony. This dwell time is a

1165 key characteristic for each system, is usually tracked as accurately as the frequencies being used and is configured by a master beacon signal for each system. The master beacon information and timing can be derived by monitoring and decoding the RF emissions and can also be obtained by direct connection to the system network and

directly interrogating any instance of a transceiver device such as 34 via data connection

1170   32 and the network 36.

A well-designed hopping system allows for code hops to be lost to likely interference, but

that the system can detect a data loss or corruption and allow acknowledgment

handshakes and/or repetition to detect lost hops, and repeats corrupted data reliably.

1175   Here the different layouts employ a different pseudo-random ordered list of consecutive

frequency channels, or a time-offset version of that list that is another orthogonal code-set

in itself. In this way, all the systems can optimally use the available bandwidth and be

protected from a non-correlated or static noise emitter in the band. If FM modulation is

used for the link modulation each hop, this provides another measure of link robustness

1180   and also allows the traffic density to be increased by space diversity.

A further benefit of this frequency agile strategy is that a codeset hopping RF transceiver

can also scan the spectrum and detect, by recognizing the modulation and data encoding

technique seen, that an older fixed frequency link is in operation and has a desired system

1185   ID to connect with. It can then change its modulation and encoding method and data rate

to be in harmony with this, and then fix its RF frequency to establish a connection or link

on this system with a fixed frequency or legacy RF data link. This is a valuable capability

that now allows interoperation of new higher capacity and capability technology RF data

links with older equipment, and that preserves the earlier investments and operations. AM

1190   modulation may also be employed alternatively to FM as the modulation method for

establishing a data link to a non-hopping system.

Figure 4 shows the configuration of a preferred embodiment for an RF transceiver. Item

86 represents an RF module that is capable of transmitting and receiving RF data. The RF

1195   control sequencing logic, 85, can be configured to connect via link 89 directly to the bi-

directional system data network, 36, or alternately to a data connection like 31 or 32 or a

directly to a decoder, as link 80. The particular mode of usage of link 89 is detected by

RF control sequencing logic, 85, and it configures its RF operations to match the

requirements for the type of link needed. This mode detection can be by coded logic

1200   states of interconnect pins or special initialization codes sent over link 89. The link 89 is in fact a plurality of control lines and signals and can exchange bi-directional data as well as control and configuration signals, such as desired RF modes as well as system ID etc.

1205   The transmit antenna, 87, is shown as distinct from the receiver antenna 88, but in fact it is most common and preferred to use a single antenna for both functions with the appropriate RF signal duplexing or other transmit/receive separation methods. RF modules 33,34 and 98 are shown with a single antenna. With most duplex RF links a separate simultaneous transmit and receive frequency allocation is used, but it is preferred to use Time Division Duplex at a higher bit rate to effectively create a

1210   simultaneously bi-directional RF link in this embodiment.

To provide frequency agility for the transmitter in RF module 86, connection 90 is provided for the RF control sequencing logic, 85, to setup and tune the desired transmit frequency. Item 91 controls the RF transmitter output power or AM amplitude and 92 controls the FM data modulation. These three control links allow the transmitter to be

1215   sequenced in carrier frequency, and data from 85 to be modulated in FM or AM modes. If direct sequence transmit operation is desired, then line 93 is configured to mix the transmit RF with a PRBS spreading sequence also generated by 85.

The receive frequency for data reception can be commanded by line 94, and the recovered FM data and AM (or RSSI) data are conveyed by lines 95 and 96 to 85 for

1220   processing and decoding. Line 97 is provided to control the receiver logic and gain control for AGC action. Note that each of the control lines shown may in fact be implemented with one or more signal wires, and some of these line functions may also be merged in multiplexed control lines to the real component interfaces for equivalent embodiments.

1225   The mode selected in 85 determines how the RF module 86 is controlled and sequenced. It is most effective to employ a dedicated control logic for the RF control sequencing logic, 85, that is a microprocessor with a plurality of algorithms coded for transmitting and receiving e.g. FM modulated frequency hopping method , fixed frequency FM and AM and even a direct sequence codec.

1230   The data sent to, received and recovered by 85 via the RF module 86 is error checked and
        formatted as needed, and then is available via 89 to other devices connected. In this way
        the complexities of the RF link operating scheme are hidden from the rest of the system
        by a now consistent data interface, and a single transceiver design can be more easily
        used in multiple ways around the layout control system to provide improved data

1235   communication and still allow connection to older or less capable RF links. The intention
        of the RF link is to provide a wireless bearer that will conduct the backbone data
        communications transparently irrespective of the data type. The preferred embodiment
        employs 25 to 64 hop channels in the 900MHz ISM band, though other bands e.g.
        2.4GHz may be employed and would be considered equivalent to this method.

1240

        Note that each throttle may be a member of a frequency hopping codeset (i.e. channel)
        and that it is also now possible for a throttle to depart from a primary hop sequence and
        then employ another secondary orthogonal codeset to establish direct private
        communication with one or more different devices. For example, throttle 28 can change

1245   its tracked primary codeset to establish a secondary direct bi-directional RF control
        channel from transceiver 33 to transceiver 98 in locomotive 40, then the throttle may
        regain the primary codeset (since the starting timing and hop sequence is known exactly)
        and re-establish the primary channel via 34 to the layout control system. Upon return to
        the primary codeset, at whatever actual hop is active, the throttle can also now ask for re-

1250   transmission if any data was held for it while it was active (and not acknowledging) on
        another secondary channel directly controlling a train, sending voice, video or sound
        data, etc.

        If train 40 is situated on tracks that have no power it may have a backup battery to allow

1255   RF control and motion, without need for a Command Station and/or booster providing
        track power. Additionally the train decoder 41 can be configured to allow a RF control
        link from a throttle or other device via transceiver 98 to be used in preference to any track
        communicated commands, so the track signal merely provides power, and battery
        recharging capability if a rechargeable battery is used. This configuration is useful

1260 alternate mode for selected parts of layouts where it is problematic to provide sufficient track power over long distances or keep the track clean enough for reliable operation.

With a digital control system, most of the data is low density and directed from the throttles or control devices into the layout control system. If status monitoring of the
1265 layout state is desired more information is then needed to be sent back to the e.g. throttles. In most cases the data can be buffered and stored and forwarded as is convenient. If the data link is expanded to multimedia then the timing becomes more critical to maintain data flow requirements and extra capacity through extra channels is useful to avoid bottlenecks. Note that throttle to throttle, and PC or Internet
1270 conversations or data exchange to a throttle are also possible.

With this novel multi-way frequency hopping control strategy, a throttle or other device can dynamically and transparently move and link to other secondary channels to exchange; direct train control, voice messages and conversations or multimedia
1275 information or other data, as needed and not interfere with basic control operations on the primary hopping sequence of the main layout system or ID. If all the secondary orthogonal codesets employ the same precise hop duration and hop in close synchrony, then a multiplicity of secondary channels are available for other control, conversations, multimedia data exchange and the like without causing interference. Since the hopping
1280 method allows many co-operating transceivers to be in simultaneous use it is also possible to extend the bi-directional system data network 36, using the primary hop or secondary hop channel/sequence to another remote instance of a bi-directional system data network to allow parts of a layout with the same system ID to be expanded without wires.
1285 Any general RF interference to a hop is handled with standard error detecting and recovery techniques to maintain all hops to optimum capability.

43

Expanded proportional control embodiments

1290　From the earlier description it is possible to construct a proportional key to act as the whistle key, item 57, for a selected or addressed decoder device, and this will provide both an on/off function capability along with a z-axis pressure sensitive proportional actuation capability for e.g. a playable whistle feature.

It is useful for the bell key, 58, and a diesel idle key, 60, to have a proportional capability

1295　as well. In all prior art systems these effects have a binary function key associated with the feature. For example the Digitrax DT400 throttle predefines; the F3, like item 61, or general purpose function-3 key command and the corresponding F3 control line in the decoder for control of an uncoupling mechanism such as a Marklin "Telex", Lionel or Roco remote electric uncoupler.

1300　It is also possible to enable a pulse-timing feature on the function lead in the decoder device to guard against the user allowing a general purpose function key (on/off type) assigned to coupler control being left on and damaging the uncoupling mechanism. Since the function keys might not have a visual indication of their present operation state, icons showing the binary state of the function keys (whether on/off) are provided as item 52 in

1305　the display.

A user may re-map any function key, and its characteristics, to any output line in the decoder by setting the throttle configuration options, or programming a similar control mechanism in the decoder.

1310　The proportional key actuation and ensuing command disclosed to this point offers a continuously variable change, increasing and decreasing by pressure, after the threshold force has been reached from the rest point.

A very useful improvement in capability is to allow any proportional command or signal

1315　level to be *latched* or frozen at a non-resting value and then allow the proportional key to be released, while the proportional command value is held fixed (or even allowed to return to the reset state at a another predetermined rate).

44

This would allow for example the diesel idle key, 60, that is operative when the speed control knob, 50, commands a zero (or stopped) speed, to prototypically 'rev up the

1320   diesel' without requiring train motion, and then be left e.g. at a high-idle rate.

To do this we can introduce an on/off *pitch* (frequency) select key, 67, that (1) when *on* allows the any other proportional function key to be enabled to track proportional commands and (2) when changing to *off*, that last proportional state is frozen. This

1325   example of the associating the key 67 with pitch select and providing other types of select keys, allows a *multiplicity of aspects* to be made proportional for each discrete effect controlled by any function key. Naturally a corresponding unique proportional command must be uniquely defined for each type of proportional effect and aspect (or channel) that is needed, though the mapping of these commands to a particular effect aspect in the

1330   decoder device can be done at the users' convenience. E.g. the pitch key can control the speed aspect of a function.

Another binary on/off select key like 66 for *volume* (intensity) may also be used in combination with the diesel idle key, 60, to modify and hold the volume of the stationary

1335   diesel and then separately, the pitch or effective engine speed can be independently controlled by the alternate combination of pitch select key, 67, and the diesel idle key, 60. Naturally the sound generator can use an additional local decision logic on the variable/proportional pitch channel information to additionally modify the diesel engine . volume to track when the engine sound is "revved up", but a separate volume channel can

1340   additionally adjust the absolute engine volume. The bell key, 58, can have its tone (pitch), volume and even cyclic ringing rate easily predetermined with appropriate binary select keys used as described here.

The display indicators, 56, are provided so the throttle can indicate, by being lit or

1345   flashing etc., which select key is in operation and encode how it is being interpreted by the control system, i.e. its mode of operation. It is useful to also have an indication of the present proportional value being commanded, since it may be hard for some users to distinguish fine gradations of force, or they may not be able to gauge the change of effect

since the decoder device may not be within view, etc. Display item 53 is one of many
1350 methods of providing such feedback to the user visually. In this case 53 is configured as a "bar graph", similar to the well known "vu meter", and this provides an indication of the present proportional value. Many types of display, indicators, meters etc. can be adapted to provide this "analog" representation in the user interface that allows a user to confidently view and set a desired proportional value without needing to be able to
1355 directly sense the effect being controlled, and these would be considered as falling within the spirit of this invention. If a text area is available on the display, it is also useful for this to optionally flash up an additional message indicating when a function effect or aspect is being selected and proportionally modified. The display and its control by the throttle control logic, 30, is an important an integral part of the user interface.

1360

The pitch and volume and other select keys are effectively "verb" keys to signify which aspect of the proportional effect to control, and the function keys are "noun" keys to define, select or focus on which effect or aspect is being modified. Each effect generator or decoder can then be configured to use any of a multiplicity of verb keys as
1365 simultaneous proportional control channels for a multiplicity of aspects, in any manner that allows maximum control capability.

This control of a multiplicity of proportional aspects of a function or effect is not limited to sound effects. For example the light key, 59, can be used in conjunction with the
1370 volume select key, 66, to set any brightness of lamps on the train (or passenger car). A flashing lamp such as a MARS light can use the pitch select key, 67, to adjust the frequency or speed of the flashes as well as volume select key, 66, for the light intensity, and these settings can be left at any desired values. The city sounds key, 63, can have the pitch select key, 67, select the phase of the day to play i.e. whether it is time for the
1375 morning rush hour, lunch time or evening sounds to be played, and the city lighting can track this to provide the correct ambient effect. Here the volume key would select the city noises volume and a decoder address would be allocated to the decoder device and sound module controlling these effects in each city. The countryside noise key, 62, can also have its volume controlled and e.g. the numbers of cow moos or sheep bleats per unit

1380 time and their density can be controlled to give a sense that the herds or flocks are

changing over the day, as well as phasing to change from day to night sounds like

crickets etc. The steam locomotive electric Dynamo speed (turbine whine) and exhaust

noise level vary by load, and these aspects can now be proportionally controlled and left

at a desired level. Note that 2 or more binary keys may also be employed to predetermine

1385 which aspect is to be modified by a separate proportional key, and this requires more

finger dexterity.

We now can use any combination of 2 or more keys, at least one of which has

proportional capability, to form a proportional control channel that can be latched

1390 **or left at a state that is not the rest-state.** If the extra binary select key is not used then

any proportional function key simply acts as a standard proportional key that returns to

the rest-state value when released. This provides a very flexible, novel and multi-

dimensional control capability for a multiplicity of aspects for a plurality of addressable

functions and associated effects.

1395

Minimizing number of proportional keys required

Note that you can make either of the select or function keys proportional and the other

keys simply binary, and just modify the sequence to allow this new latching capability for

that configuration. It may be beneficial to minimize the number of force sensing keys to

1400 lower cost.

For example as an alternative embodiment, if keys 66 and 67 are now configured to be

proportional then we can have the function keys 57,58,59,60,61,62 and 63 be less

complex (and costly) binary (on/off) function control keys. In this manner a proportional

volume key, 66, in combination with binary key 61 can control the loudness of the

1405 coupler clank activation, and a proportional pitch key 67 in combination with 61 would

control another coupler proportional aspect like how many discrete clank events would

occur, as being proportional to the train length.

The sequence of activations between a proportional key and a function key can also be

1410 used for expanding the control repertoire, such as a double click of the function key can

47

enable another aspect of the function to selected, much like a shift mode, e.g. a double-click of the bell key would allow the pitch key to now control the bell ring rate instead of bell pitch/tone/timbre. A proportional select key, 66 or 67, operated without a function key could control a basic key aspect such as overall decoder volume or pitch for

1415   proportional Doppler simulation for the decoder address selected.

Note that prior art sound decoders such as those by ESU allow sound volume, some pitch ranges and variations in sound effects, and control flags for these, to be selected by CV programming defined by NMRA RP-9.2.3. These CV adjustments may be used in conjunction to fully proportional control taught here, but are relatively clumsy and not as

1420   comprehensive and accessible as real proportional control.

In summary, by using a proportional key in time sequenced combination with one, or more, other binary key(s) it is possible to expand proportional control to selection of different control aspects of a function or effect and allow the latching of this proportional

1425   value. The important action is the use of multiple keys in combination and sequence.

Although the train speed controlled by knob 50 is defined as not being a proportional effect in this invention, it is possible to use this as a proportional (verb key) input in combination with some function keys. Since the speed control is considered as always

1430   active for a selected decoder while it is possible to change a function state, this multiple use is awkward but can be achieved by using another sequence or other key to change the speed knob, 50, usage to allow a proportional capability. For example if the light key 59 is held down and then the speed knob, 50, is pressed down to enable its switch, then a proportional lamp brightness command can be generated by turning the speed knob while

1435   it is pressed down. Release of key 59 or the speed knob switch would end the proportional light command, and the speed knob can revert back to train control. Using an encoder for the speed knob sensor makes reversion to prior train speed easiest. Note that if the speed knob is not pressed down then the light key 59 reverts back to binary function control of the light using the last brightness setting.

1440

Proportional effect creation and filtering

A fully proportional control by a key can be quite sensitive to the amount of key deflection (depending on mechanical compliance) and even with an analog readout of the present proportional control value it may be too "twitchy" for persons with poor fine-
1445   motor skills or hand-eye coordination. It is useful to be able to subject the proportional command to a filtering effect prior to its being transmitted to the system. A good example of this would be low-pass filtering of the key proportional/variable force information after the force threshold is exceeded. If this key variable force data is now fed through an electronic integration process (equivalent to low-pass filtering), for
1450   example in software or equivalent, it is possible to have a perceived desensitization of the key action, since now the proportional commands are the result of the summation of key force over time and seem to be acting more slowly. The integration rate (sensitivity) can be adjusted from no effect (high speed/standard response) to a very slow effect (maximum integration/filtering). In this way rapid key changes can be smoothed out and
1455   the user feels an extended response is possible by adding the dimension of the duration of key actuation *along with key force* to the proportional control. An excessively slow integration effect will limit the possible rate of change the user can obtain. The amount of raw proportional force in fact controls the slope or the rate of change of the integration process.
1460   In fact with this novel configuration a binary function key using a filtering method would provide a proportional control capability without the need for a force sensor. This is unlike the Marklin playable whistle control with a binary function key varied in actuation time, mentioned earlier, since the key press and following filtering and control logic actually develops a controllable and varying proportional *command value* that then is the
1465   input to the control system and then to the track, whereas the Marklin sound generator creates a variable pitch whistle in response to a timed binary command from the track.

On a real layout, as happens in the prototype, as a train moves around an area it is expected that the echoes and reverberation will change. An aspect of a proportional
1470   command channel is a good choice to allow the onboard sound generator to modify a simulated reverberation capability. If location detection is employed then it is useful for

this proportional reverberation effect channel to be monitored and automatically controlled by a device on the layout control system.

1475 In the real world, that we wish to emulate with the closest realism, a true Doppler effect and its rate of change is proportional to the vector speed of the train (relative to the speed of sound) and position of this source (train) relative to the observer's *position*. Thus the Doppler shift needs to be adjusted for the correct pitch, amplitude and *rate of change* and timing for the user position in 3 dimensions relative to the layout and the actual train. The

1480 pitch rate of change is directly affected by the varied geometry of the observer's position, so the Wolf simulation is limited and can at best only be accurate for one layout position and command initiation time. Incidentally, this well-known Doppler rate of change phenomena is used in satellite position measuring systems such as; the Iridium and Orbcomm satellite telephone systems, the old US Navy "Transit" SatNav and the more

1485 modern Cospas-Sarsat emergency beacon system.

The Wolf Doppler simulation method only allows one control degree of freedom, and this is the start time of the effect that is controlled by the user interface. Note that this Doppler effect is simulated, since it is not created by the physical velocity of the moving

1490 model train, but a pre-distortion of the character of the sound emitted by it, since the model moves very slowly compared to the speed of sound. In fact, it cannot accurately be termed a "Doppler" effect since its limitations do not fully model the real world. It is more properly defined as a predetermined variable pitch effect.

1495 Employing the superior proportional control channel capability of this invention, the user now has multiple degrees of freedom and can thus realistically increase pitch and volume by an adjustable and desired amount *and rate of change* for an a approaching train when it is appropriate, and then conversely reduce these effects as the train recedes. This type of multiple degrees of freedom control is fundamentally and clearly different and superior

1500 to the single degree of freedom approach of the prior art, which cannot fully implement an accurate Doppler effect simulation for the observers. The new method is able to correctly and accurately model the real Doppler effect as it would be observed by an

operator at different locations, and thus is distinct from the effect claimed by Wolf and also discussed by Severson.

1505

A decoder device is typically a small portable electronic module that employs hardware and/or software to detect and execute commands from the track control waveform. This type of decoder function is not limited to small devices connected to the tracks and in fact can be programmed into, for example a PC or specialized processor running surround

1510   sound capability with a signal interface to intercept the track control waveform, or a connection to the bi-directional multiple-access data network to directly receive any proportional commands broadcast.

Expanded track control signals

1515   Prior art such as the Digitrax DCS100 Command Station allow the interleaving or interspersing of DCC and Marklin Trinary control signals to expand the control capability and increase the types of decoder devices and trains that can be run on a layout. Now it is possible to allow decoders to automatically detect and select one of a multiplicity of track encoding methods and operate with it. A further useful expansion is add a new

1520   interspersed encoding with a significantly higher data throughput to allow larger numbers of trains to operate with reduced latencies or delays and allow other types of digital data to be sent via the tracks such as programming, sound or multimedia information.

Figure 5A show a prior art DCC waveform example. At the left side the first encoded "1"

1525   data bit is shown as a low period half-cell followed by a high period half-cell. The half-cell period of a DCC "1" is typically 58 microseconds, so it takes a track cycle of 116 microseconds to encode a "1" data bit. Scanning to the left is then a "0" data bit with 2 half-cells of 116 microseconds and then another "0" data with the last high level half-cell of an zero-stretched value to provide DC offset for legacy train control. Finally a "1" bit

1530   is depicted that is intended to be a "packet end" bit of a DCC packet, and after this DCC packet completion and even some extra "1" bits it is possible to transition to a different track encoding method, such as Marklin Trinary.

The DCC timing provides a square-wave track waveform with a low effective frequency

1535   to mitigate RFI concerns but is limited to a fastest data rate of "1" bits taking 116

microseconds. This is limiting for a large number of trains or if it is desired to send

multimedia sound, data etc.

Figure 5B shows and improved encoding waveform that can be used for format

expansion and is compatible with existing track boosters and decoders. Here the

1540   waveform is shown starting with a DCC packet end "1" bit and then transitioning into an

"A" cell. This "A" cell is shown with 3 alternate widths, by the 3 downward arrows so

that each discrete width possible for the "A" cell can encode 1 of 3 possible code values.

The following "B" cell also is shown with 3 possible widths, so this cell can also encode

3 possible values. If the "A" and "B" cells were 58 microseconds each then the

1545   combination of pulse widths of these 2 cells would encode 2 sets of 3 choices each,

versus just 1 choice for a DCC "1" bit, which yields a big improvement in data

throughput on the same track infrastructure. The new encoding is effectively a phase

encoding where the start edge of a cell is at a fixed repetition time, and the harmonic

content is dictated by the phase variations employed. By choosing a sensible repetition

1550   frequency and limiting the minimum pulse width, it is possible to control the RFI to

acceptable levels with a square-wave track signal. Note that it is not possible to employ

more advanced phase encodings such as QPSK or Trellis codes without modifying the

track signal and boosters to allow more complex multiple voltage levels, and this would

not then be compatible with existing DCC Command Stations or track signal boosters. It

1555   is also not possible to provide legacy DCC zero-stretch control of conventional DC trains

for the duration of the improved phase-encoding.

A convenient phase-encoding example would be a 10 microsecond minimum pulses

(waveform high and low times) and 16 width encodings of 2 microsecond increments,

that would form a total repetition time of 52 microseconds (10+32+10= 52 uS). With this

1560   example, we would encode 32 phase states or 4 binary data bits in 52 microseconds. This

would be about 8 times faster than the best DCC signal. We can choose a different

repetition rate, minimum pulse widths and number of phase steps to yield any system

throughput and RFI performance desired.

52

The phase step size is chosen to allow a decoder to reliably time and discriminate the data

1565 encoding increments even when there is pulse distortion in the track waveform due to; voltage slew rates, conduction crossover discontinuities, load variations and any pulse timing distortions. To measure the pulse timing distortion, which can change by track load etc., it is useful to transmit training patterns of known values either at the start of a improved encoding packet burst, or cyclically as a calibration, which the decoder device

1570 can detect and infer the distortion and hence create an internal calibration table and algorithm to correct subsequent measured pulses for distortion.

Figure 5C shows an example of 3 phase-encoded cells starting a phase-encoded type of packet after a DCC packet end bit that are used to allow compensation for pulse distortion. This shows first a minimum phase, then a mid-value phase encoded and

1575 finally a maximum phase encoding. Now the decoder has 3 known points to infer timing distortions and can update its internal compensation algorithms accordingly to ensure reliable detection. More than 2 points of known data to pulse width encoding and time measurement, and 3 or more are preferred, and these are pre-determined so the receiving decoder can perform the pulse distortion measuring function as needed. An excessive

1580 number of training pulses increases the coding burden and lowers the time available for channel data and does not add much improvement to data reception or accuracy.

Each cell can now phase-encode a discrete number of states, which then represent a number of binary data bits encoded. To improve reliability it is possible to trade off the

1585 bit-rate to have more complex encoding rules to detect and correct most common bit or burst errors. For example, if each cell encodes or quantizes for 16 distinct phase timings or 4 binary information bits, it is possible to use 2 cell pairs to derive 8 coded bits per pair of cells. These 8 bits can then be coded using a coding system of a chosen minimum Hamming distance of 2 to allow any 1-bit error to be corrected, and now 32 states or 5

1590 bits are transmitted per raw 8 input bits. Higher levels of detection reliability and correction can also be employed with lower throughputs, by trading off coding entropy. Thirty-two phase increments can encode 5 binary bits, but with the need for more accurate time resolution in a decoder. The actual phase timing encoded can be mapped in any way to the input code bit patterns for each cell.

1595   The phase-encoded waveform can be constructed as detailed here, and suitable pulse

timing choices ensure that a legacy DCC or Marklin Trinary decoders will always see the

interspersed phase-encoded packets as errors and reject them while still correctly

operating on the intersersed packets they are designed to decode. A variable zero-

stretched DCC "0" bit cell cannot be mistaken for a phase-encoded digital code cell

1600   because of its long time duration. Additionally this zero-stretched "0" bit does not

actually encode any digital information but rather, allows the waveform DC balance to be

controlled.

Using this improved phase-encoding method a higher speed control and communication

1605   strategy can be formed with minimal impact to existing investments in the layout control

system, decoder devices and trains. The packets and commands encoded by the improved

method can be formed broadly using the same methods as for DCC or Marklin formats

with the addition of noted pulse distortion measuring mechanisms. The greater data

throughput now allows more trains to operate on the layout, and can allow multimedia

1610   data such as real-time sound to be sent to an addressed decoder device. The Command

Station, 37, can be upgraded to selectively form these phase-encoded packets as needed

along with other square-wave signals.

A further improvement is the control capability of the system is to allow the Command

1615   Station, 37, to be expanded in multi-format track waveform control signals, in addition to

intersersed square-wave digital control signals like prior art mixtures of; DCC, Marklin

Trinary, Trix and FMZ formats etc.

Since the square-wave track signal generators and track drive booster outputs are band-

1620   limited to ensure RFI compliance with e.g. FCC and CE requirements, it is possible to

add compliant AC-coupled low level RF signals encoded for digital commands into the

square-wave track signal to establish other control links. Item 81 represents a module that

can create an RF digital command signal from data conveyed over the connection 82

from the Command Station, 37. Connection 82 can also link directly to the network, 36,

1625   as an alternate arrangement. The output of the RF digital command signal generator, 82,

is then combined at track connection 38 with output of Command Station, 37, to form a new expanded mixed track signal.

This is unlike the Keith Gutierrez CTC-16/CTC-2000 art, and is distinctly different from
1630   the Wolf '681 art because the "power signal" now is a separate digitally encoded waveform that is itself capable of simultaneously digitally controlling a multiplicity of different address trains with all control aspects, whereas the AC and DC "power" of Wolf has limited control aspects aimed mainly at legacy trains.

The early 1990's Lahti "Dynatrol" system and the Keller "Onboard" system both used
1635   low frequency RF analog control waveforms (or non-audio tones) impressed on a DC power signal. There were limited attempts in 1994 to put the Keller waveforms on a DCC signal to allow legacy interoperability, but the underlying RF modulation was analog in nature and limited and not of the sophistication of a digital control capability.

1640   So, one or more encoded RF digital command signals added to a square-wave digital control signal represent an expansion of control capability. In particular multiple RF digital command signals or channels can be implemented with different carrier frequencies and channels, hopping carrier frequencies or even a direct sequence spread spectrum method. In this way a decoder that understands an RF digital command signal
1645   format that operates on an AC or DC powered layout can also be compatible with a square-wave based system, such as DCC, and can then be inter-operated with greater flexibility by using this novel configuration.

The track RF digital control signal now is conducted by the track system as opposed to
1650   being radiated through the air from a throttle or other emitter, but the decoder can automatically detect and use an RF signal by either route if it is of sufficient strength to be detected.

Note that a frequency hopping system may be advantageous here, since they are simpler and lower cost than direct-sequence spread-spectrum and any propagation, multipath or
1655   reflection problems are strongly related to frequency. Here the hopping system can dynamically search for and track a good reply from a decoder device to establish a good

hop channel and preferentially employ these many possible good hops. This allows a system to inherently avoid rail RF transmission problems such as those noted earlier by Besoughloff. It is also possible to easily configure a multiplicity of separate outgoing RF

1660   digital commands to cooperate so they do not interfere with other RF signals on the tracks such as live video and sounds from cameras onboard the trains, or other multimedia signals etc.

The actual form of RF modulation or encoding of digital commands can follow prior art

1665   examples used for establishing a RF communication channel in a noisy and fading channel environment. There are 4 important features that must be included in the RF digital signal: (1) a synchronization burst to mark the start of a message in the RF channel (and to allow AGC or clock recovery action), (2) an address or routing part that allows an addressed device on any layout to determine the correct recipient, (3) a

1670   command part that encodes commands and data required for execution of these and (4) an error detection capability (that can include error recovery, such as ECC or Fire codes etc) to ensure a valid message reception.
These features map easily into a fixed frequency or frequency hopping based RF digital signal and these can use any of the well known modulation schemes such as FM, AM,

1675   Phase Modulation, BPSK, QPSK, Gaussian MSK etc.
For a direct-sequence spread spectrum type RF signal the clock recovery and data/error recovery are well known demodulation capabilities of this technique, [e.g, as taught in "The ARRL Spread Spectrum Sourcebook" ISBN 0-87259-317-7, published 1990], but the addition of a error detection coding separately over the digital message and the use of

1680   AGC provides and improved reliability. A direct sequence method allows a coding gain that de-correlates other PRBS coding keys and noise so as to provide co-channel capability in the same spectrum, but then practically requires all other similar power emitters to use this more complex link scheme to avoid interference or noise encroachment.

1685   A direct sequence system can be either continuous-mode or discontinuous mode of transmission. It is also possible to use the square-wave edges or identifiable transitions of the underlying control or power signal to provide a fast locking timing reference point to

speed up the clock-recovery and cell boundary correlation if a non-continuous

transmission direct-sequence modulation method is in use. This timing point allows the

1690   RF decoder to make pre-determined assumptions about the timing and phase of the

following direct sequence fragment so that a full correlation window search of clock rate,

phase and data cell timing is not required and synchrony can be greatly accelerated.

Expanded detection capability

1695   With an RF digital control waveform imposed on a square-wave control signal, or even

an AC or DC power signal, it becomes problematic to track and detect feedback from a

train decoder device to localize position, because RF signals are notoriously sensitive to

conductor paths for propagation.

To localize a responding decoder device it is possible to discriminate the particular track

1700   section and associated detection sensor the addressed decoder device is on. For an

encoded current pulse reply items 48 and 49 are configured to detect the reply with prior

art types of current detectors and methods.

If the reply is coded as an RF signal then it is harder to reliably localize which sensor any

RF reply current is passing through. To solve this problem directional couplers 83 and 84

1705   are added to sense the RF currents in the individual track feeds and sections, and the

measured data is returned to the detection system, 47, that has an RF detection capability

added. The directional coupler allows the relative strength of both the current (a) to the

track and (b) from the track (reply) to be measured, so it is possible to know when a reply

as RF current, is coming *from* a track section. Depending on the RF frequency in use a

1710   common implementation of the directional coupler is a closely coupled set of

transmission line segments. Alternatively, if the frequency is below about 20MHz, then

it is better to use a discrete component hybrid transformer (or bridge) approach to

discriminate the currents to or from the track. Since there may be multiple emitters in a

track section using a direct-sequence reply method, it is desirable to turn off the RF reply

1715   during the known reply period for all but the addressed decoder device, although the

reply channel which has RF current from the track can be decoded to determine which

emitters are actually present. Decoding multiple replies can be affected by the VSWR or

track reflections, which can cause problems. For a frequency hopping RF system the

discontinuous nature of the signals allows the RF replies to be easily discriminated. Once
1720   replies can be localized then it is a simple matter to use prior art to from a bi-directional
data link that allows position detection.

Expanded decoder capability

A synchronous data connection configured from at least two *existing* general purpose
1725   function leads such as item 77 of figure 3, when connected to an external expansion
module, such as a sound generator, 42 (shown with a speaker), provides a new capability
to a decoder device. The addition of a proportional control command in the repertoire of
commands exchanged over this synchronous data connection allows an expansion device
to be added at the convenience of the user, at a point when the extra cost and capability
1730   are justified.

Since the sound EEPROM or FLASH memory, control and readout logic and the A/D
conversion method (i.e. conversion of digital sounds codes to a signal appropriate to be
conducted to a speaker), and external amplifier needed for sound capability represent a
dominant and real cost, and take up volume in a module, it is efficient to not burden or
1735   bloat a compact decoder device with this capability.

The addition of this sound (or other expansion) feature to the decoder installation is then
as simple as plugging the sound generator, 42, into the decoder, 41, and then configuring
the appropriate decoder general purpose function leads, 77, to change mode to support
the synchronous data link. At least two lines are needed, a clock line and a data line to
1740   create a clocked or synchronous data link where the data is valid and sampled at a
predefined clock transition. The synchronization of clocked data bits into discrete bytes
out from the decoder device (or in) can be indicated by providing a recognizable pause in
the clock pulse stream to demark a command start. Additional function leads may be
employed to flag byte boundaries or demand attention at the interface, but these are a less
1745   efficient use of the function lead resources. A multiplicity of bytes (and even extra bits)
are sent per command to allow for a command type encoding, data arguments and
possible error check information. The clock and data rate are pre-determined and can be
as fast as needed to provide control. The majority of operating state information across
the synchronous link is directed toward the expansion unit (e.g. a sound generator) but it

1750 is possible to configure the data line for read back of acknowledgements and data if this is required.

A multiplicity of sequential commands over the synchronous data link continuously convey the current control states known in the host decoder device such as, at least;

1755 function states, throttle speed, present speed motor load, proportional channel values, control and address CV's etc., and it is beneficial for the synchronous data to be updated as a priority when any significant state change is seen. If no state changes are seen, it is possible to simply refresh all the information in sequential order until a change needs to be communicated at the next possible update period. Since the function lines changed

1760 from general-purpose use for lamps etc., are not now available for anything but the synchronous data link, these can be restored as outputs from the expansion module, e.g. sound generator, since all the function state information is sent over the synchronous link. For example, if F1 and F2 are converted to synchronous mode use, then the sound generator can recreate these lines as well. In fact on many DCC systems, F1 is

1765 commonly allocated to bell control and F2 for whistle control, so these functions in this example would be used solely for sound control and would not have a meaningful use as recreated general purpose function output lines for e.g. lamps or smoke unit etc.

Since the current motor speed and load must be calculated to be conveyed by the

1770 synchronous data link to e.g. a sound generator, this data may also be employed within the decoder to provide scalable speed stabilization to the motor. A further refinement is the modification of the speed stabilization in sympathy to the type of sound module connected and how it is configured. For example a diesel and steam unit have different droop characteristics under load, so a droop CV for scalable speed stabilization

1775 adjustment can be modified based on the sound generator. A cam timing input to the sound generator, 99, for timing e.g. a steam chuff can also be fed back into the decoder to affect the motor speed control as well as modifying the sound generation scheme.

One benefit of this arrangement of two devices is the fact that it is easier to install two

1780 smaller modules within the confined spaces of a locomotive. It is cheaper to replace or

repair only one of two elements if one fails. If the sound or other expansion is not desired in a train, or is impractical due to e.g. size constraints, the decoder can beneficially use the synchronous data link leads as originally intended as direct functions controls for; lights, smoke generator, un-couplers, door opening actuators etc. The sound unit or

1785 decoder can also be changed individually to improve features at lowest cost and impact to the other unmodified unit.

The synchronous data link is also configurable to conduct commands that allow the downloading of new encoded sound and configuration data while the decoder and data link are active on the tracks, and this data can also be real-time streamed data for the

1790 speaker that is interspersed and conducted via a fast-digital track expansion format.

Note that the sound generator can also have its power leads connected to the track, by connection 78, and if this connection is detected to be in effect, automatically change to receive and decode new commands directly from the track waveform. In this case, the

1795 synchronous data link is *still* operative and is used to receive data from the decoder that must be synchronized to the motor state, such as; present speed and load and when the motor actually changes direction or stops which are affected by the back-emf adjustments and motor characteristics. By selectively decoding commands and data via track connection 78, the sound decoder can make use of expansion data formats of e.g. a phase-

1800 encoded expansion signal to obtain real-time sound for output or new programmed sounds to store in Flash memory or EEPROM, to add capability without possibly obsoleting the host decoder.

A steam sound chuff is effectively a variable duration pink-noise impulse of steam that transits the drive cylinders and then is acoustically filtered by the resonant cavities of the

1805 smoke box and smoke stack. This forms the chuff that is heard by an observer. Additionally there are cyclic noises from the valves, controls and steam cylinders and other items, but the predominant sound is from the smoke and steam exhaust. Instead of recording several examples of the locomotive at discrete load levels as done with prior art it is useful to model a recorded chuff or pink noise event and then modify this

1810 continuously by trainload. In particular the steam pulse timing varies over a known range and so an original long duration fixed pulse steam chuff waveform may be

mathematically adapted to emulate the varying steam pulses. The attack and decay envelopes of the steam pulse change with load, but the predominant change is in width of the chaotic-flow steam pink-noise sustain envelope between these. Accordingly it is

1815 possible to selectively remove or filter sound fragments from the long sustain envelope to develop a shortened or higher rate chuff pulse. Since steam has dynamic mass and pressure effects as its flow varies, as the speed and trainload changes the volume, pitch (harmonics) and low frequency components change in an amount that can also be added to the pulse simulation. These three modifications to a representative long chuff, in a

1820 blended configuration can calculate a simulated steam chuff that is responsive to a continuously sensed speed and trainload measured from the motor load and back-emf information that is available over the synchronous data link. Since some of the sounds are from a more distant cylinder on the other side of the locomotive it is also possible to model the nearer-further cylinder amplitude effects of a compound engine from a single

1825 chuff as well.

Having thus disclosed the preferred embodiment and some alternatives to this

1830 embodiment, additional variations and applications for this invention will be apparent to those skilled in the art of decoder, layout control system and electronic design, with minimal extra effort. Therefore, while the disclosed information details the preferred embodiment of the invention, no material limitations to the scope of the claimed invention are intended and any features and alternative designs that would be obvious to

1835 one of ordinary skill in the art are considered to be incorporated herein.

Consequently, rather than being limited strictly to the features disclosed with regard to the preferred embodiment, the scope of the invention is set forth and particularly described in the following attached claims.